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PRINCIPAL TECTONIC ELEMENTS OF TIAN-SHAN

by

N. M. Sinitsyn and V. M. Sinitsyn

This paper deals with the tectonics of the Tian-Shan mountain system within its oro-aphic boundaries, including its Soviet and Chinese portions. The general regional structural .n of the Tian-Shan is given, as well as a brief description of the folded province and of ies of different ages.

* * * * *

INTRODUCTION

The Tian-Shan is one of the major moun-n systems of Asia stretching latitudinally m the Turanian desert plains to the east-1 reaches of the Gobi, a distance of about 500 km. Lengthwise, the Tian-Shan is : inferior to the Urals but is more than ce their width. Tectonically, the Tian-in is a complex folded province with a g history of development. In its Ceno-c structure as reflected in the present ography, the Tian-Shan is a complex ift broken by interior depressions into lividual ridges and massifs, several tens number. The summits of its main ridges e up to 4,000-5,000 m and over, and are rered over wide areas by eternal snow.

The international boundary divides the in-Shan into two unequal parts: the smaller stern part located in the U.S.S.R., and eastern part belonging partly to the inese People's Republic (CPR) and partly Mongolia (MPR).

The eastern part, the longer but narrower e, is clearly defined by two vast plains, Tarim in the south and the Dzhungara in north. Westward, both plains become rrow and close off extended intermontane tonic valleys; the Alai and Borotala-ksuy, which make up the Tian-Shan indaries, where it approaches the Kunlun mirs) and the Kazakhstan folded province.[1]

To the east and west, the Tian-Shan gradually gets lower and levels off, not all at once but in groups of ridges in different longitudes. To the east, the first to disappear (at 88° meridian) are the south chains; the interior ranges persist as far as meridian 90°, but the northern ones reach into Mongolia where they are cut off by diagonal depressions and ridges of the Altai range, in connection with a wedging out of the Dzhungara massif. In the west, the Tian-Shan ranges, "split" by the Ili, Chuya, Fergana, and Zeravshan depressions, spread out fanlike and soon die out among the Turanian plains.

At the present time, the western part of the Tian-Shan, within the U.S.S.R. is the better known; it is treated in a voluminous and diversified geologic literature, and in tectonic schemes proposed by different authors.

The eastern Tian-Shan, beyond the international border, has been less intensively studied, and only in the last decades a small portion of it was covered by geological surveys of various scales, with the remainder known only from reconnaissance. All of the data on the East Tian-Shan are incorporated by V.M. Sinitsyn and A. Kh. Ivanov, in a geologic map of Sin'-Tazian, now being published by the Chinese People's Republic (CPR). Thus, it is possible to tie in the data on both the East and West Tian-Shan and to present a general picture of the geologic structure for the entire mountain system and its orographic boundaries. This is the purpose of the present paper. Because of a lack of space, only the tectonics of the Paleozoic geosynclinal stage is considered,

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[1] According to other ideas, the Dzhungara atau is fully included in the Tian-Shan.

passing over the peculiar post-Paleozoic features of the Tian-Shan structure and the Pamirs tectonic zones. For the same reason, the authors are unable to review other investigators' ideas on the Tian-Shan tectonics, as published during recent decades.

The Tian-Shan is a Paleozoic folded structure made up of a great number of individual tectonic zones different in age and structure, and in the composition and age of their sedimentary rocks and magmatic phenomena. The location of the most important of these zones is shown on the map. A brief description follows.

Before dealing with the Tian-Shan, however, we shall touch upon the major structural features of the bordering plain provinces of the Tarim and Dzhungara massifs.

The Tarim massif is a comparatively stable segment of the crust hemmed in between the folded Paleozoic Tian-Shan and Kunlun belts. It is irregularly rhombic in plan, bordering on all sides on groups of regional faults which control the structural and facial zones and the major elements of folding in the enclosing Tian-Shan and Kunlun mountain systems.

Beginning with the late Proterozoic, the movements of the Tarim massif were marked by their poor differentiation, low rate of movement and small magnitude; because of that, its sedimentary mantle is rather thin and remarkably constant in lithology. The mantle beds of the Tarim massif persist undisturbed or with only local dislocations of a flexure type [10]. The massif had acquired its platform character prior to the Sinian epoch whose deposits are a part of its sedimentary mantle.

Most of the Tarim massif is a plateau at an elevation of 800 to 1,500 m; it includes the low Kel'pin ranges and the Kuruk-Tag that are both orographically closely related to the Tian-Shan; and the Tekelik-Tag Mountains, linked with the Kunlun.

The Tarim massif basement is exposed only in a few local uplifts along its boundaries with the Tian-Shan and Kunlun (principal among these are the Kuruk-Tag and Tekelik-Tag). It is made of ancient crystalline rocks divisible into two series, by the intensity of their metamorphism: the gneissic schist, possibly Archean; and quartz schist, tentatively assigned to the Proterozoic [12].

The sedimentary mantle is sufficiently full and thick only along the Tian-Shan edge of the massif, where it is represented by a blue sand and shale interval with tillite-like rocks and effusives (up to 1,000 m thick), Cambrian and Ordovician limestone (800 to 1,200 m), red Middle Paleozoic sandstone and siltstone (500 to 700 m thick), and by a very lithologically diversified Upper Paleozoic which, despite its very limited thickness, not over 250 m, contains all of the Carboniferous and Lower Permian. In its near-Kunlun part, the Paleozoic of the massif is represented by Carboniferous and Permian beds, directly underlain by pre-Cambrian metamorphics.

The edges of the massif are mostly depressed; the Kuchar downwarp lies at the foot of the Tian-Shan (between Ak-Su and Bugur), with the Yarkend downwarp on the western Kunlun boundary. The sedimentary section of these downwarps begins with brown conglomerates and sandstones (500 to 600 m thick), apparently Upper Permian in age. The Triassic is represented by red-purple sandstone with intercalations of clay and gravel (200 to 300 m thick). The Rhaetian and Jurassic deposits above are characterized by their green-gray color, an abundance of plant remains, and the presence of coal. They are characterized by a greater thickness, locally up to 2,500 m, and by a considerable development of coarse sandstone and conglomerate [2]. The Cretaceous is marked by red sandstone and layers of conglomerate and clay (800 m). The Tertiary consists of red Paleogene and buff-gray Neogene-Pleistocene deposits. The Paleogene is made up of sandstone and clay with beds of marine limestone and marl in the Yarkend downwarp, and with gypsum and salt in the Kuchar (400 to 500 m thick). The Neogene includes buff sandstone and clay and gray conglomerate, whose thickness in the foothills is measured in many thousands of meters.

In cross-section, both downwarps of the Tarim massif are asymmetrical, because of a greater subsidence along parts adjacent to the mountains and the boundary faults. The overall thickness of the Mesozoic and Cenozoic in the zones on the mountain side of these downwarps, and the corresponding magnitude of their subsidence, are 4,500 to 7,000 m, which approximates the magnitude of the uplift of the adjoining parts of the Tian-Shan and Kunlun (5,000 and 7,000 m). The single facies zonation in these downwarps reflects the source of their clastic material in the regions of active uplift along the mountain edges, with the interior of the Tarim massif a long-enduring, gently uplifted plain not subject to either intensive denudation or sedimentation of any magnitude.

The Dzhungara massif is a slightly mobile segment of the earth-crust, hemmed in by the folded provinces of the Tian-Shan, Altai, and East Kazakhstan. Its western part, corresponding to the Dzungara plain, is

ly differentiated; its sedimentary mantle rently is not everywhere dislocated; how-, its eastern part, including the Kara-li highlands, Nomin-Gobi desert, and erous groups of small volcanic cones, rwent more intensive tectonic move-ts related to the junction of the Tian- and Altai geosynclinal provinces in this . It is broken by faulting into many ks displaced differentially; its (sedimen-) mantle has been dislocated throughout entire area.

he basement and the lower sedimentary of the Dzhungara massif lie at a con-rable depth; therefore, their composition structure are unknown. However, at both east ana west termination of the Dzhun- plain -- in the Beydzhin-Tau range and e lower Kuarcha-Tau range -- exposures recambrian metamorphics which appear e uplifted basement blocks are present.

the Beydzhin-Tau, the basal sedimentary overlying the Precambrian metamor-s belong to the Middle Devonian, while e Kuarcha-Tau they are Visean. This s substance to the belief that the Lower ozoic is missing throughout the Dzhun- massif, with areas where the Middle ozoic, up to the Tournaisian, is missing, vell.

he Upper Paleozoic section of the mas-is marked by its extremely complex position and the abundance of volcanic s. Principally, it is represented by rted sandstone, metasiltstone, and e, with thick conglomerate, tuff, and layers, both acid and basic; not uncom- in the sand and shale series are fossil-ous limestone beds. The thickness of Upper Paleozoic at the Tian-Shan bound- reaches 3,000 to 4,000 m.

he Mesozoic-Cenozoic deposits are ributed throughout the massif, but they in their full section and maximum thick-s only along the Tian-Shan boundary. e the Mesozoic-Cenozoic section opens a sequence of red conglomerate sand shale, which yield bones of Triassic iles. Higher up, there lie gray carbona-us Rhaetian and Jurassic deposits, fol-ed by multicolored Upper Jurassic sand-e and clay, Cretaceous and Paleogene beds, and finally the brownish, green, gray-yellow arenaceous, argillaceous conglomeratic Neogene-Pleistocene ies [9]. The overall thickness of the sozoic and Cenozoic in the Tian-Shan hills is 7,000 m. The Mesozoic and ozoic South Dzhungara downwarp, like similar boundary downwarps of the Tarim on, underwent but a partial inversion in row foothill zones where the effect of the giant Tian-Shan uplifts was felt; over the body of the downwarps, the subsidence and sedi-ment accumulation have continued into the present, with the Mesozoic and Cenozoic beds, as a whole, practically undisturbed.

TIAN-SHAN

The features of the Tian-Shan are its well defined linear extension and a zonal structure manifested in different degrees. In the broadest outline, this tectonic zona-tion is expressed in a juxtaposition of Cale-donian and Hercinian structures. The Cale-donids form a fully isolated belt traceable throughout nearly the entire length of the mountain system; the Hercinids are repre-sented by two belts (northern and southern Hercinids) on either side of the Caledonian backbone of the Tian-Shan.

The picture suggested is that of a consecu-tive but intricate growth of the Tian-Shan, by involvement in uplifts, of ever younger folded zones. This is graphically demonstrated in its eastern part where the Caledonian body, located in the province of interior basins and ranges, is fringed by Ordovician and Silurian folds of the northern and southern ranges which, on their outer edges, are even younger structures involving Carboniferous and Per-mian deposits.

To the west, these principal folded zones of the Tian-Shan widen abruptly, with simul-taneous complications in their structure. In the territory of the U.S.S.R., a part of the Caledonian belt and that of the northern Hercinids is present beyond the orographic confines of the Tian-Shan and spread into the adjacent regions of the South and Central Kazakhstan. Accordingly, two main belts are recognized within the Soviet Tian-Shan; the greatly enlarged south Hercinid belt sprawling from the Hissar range to Kara-Tau, and the Caledonian belt embracing the northern ranges of the Tian-Shan.

CALEDONIAN FOLDED PROVINCE, WITH PRE-PALEOZOIC STRUCTURAL ELEMENTS

The structure of the Tian-Shan Caledonids is extremely complex and inadequately known, even in its main features. In a broad sense, the Caledonids comprise all of the Lower Paleozoic folding with subordinated remnants of pre-Paleozoic structures and vast areas of epi-Caledonian to Middle Paleozoic forma-tions so very characteristic of the northern ranges of this province. In a more restricted sense, the term applies only to the south

part of this province, which is devoid of filled-up Middle Paleozoic downwarps of any significance.

PRE-PALEOZOIC STRUCTURE OF THE CALEDONIDS

A pre-Paleozoic age of the metamorphic schist structures is ascertained stratigraphically only for the western spurs of the Tian-Shan and in the Kara-Tau range, where they are unconformably and transgressively overlain by Lower Cambrian. Until recently, the pre-Cambrian age of the crystalline schist and of the structures involving them, was oftentimes determined only by the degree of their metamorphism. Therefore, many investigators were not inclined to regard the crystalline schist of the Tian-Shan Caledonids and Hercinids as necessarily pre-Paleozoic [7]. The repeated finding of Cambrian faunas in the lower beds of what formerly was thought to be the Ordovician, makes it possible to assume a much wider Proterozoic (and Archean) development than is shown on many geologic maps [5]. A geologic map of eastern Central Asia, scale 1:500,000, now about to be published, shows considerably larger areas of Precambrian exposures in the Tian-Shan.

The Archean elements of crystalline schist and gneiss, as tentatively designated, are recognized only locally and on a restricted scale: in the ridges of the Chu-Ili water divide, in the basins of rivers Chu and Sary-Dzhas, and in the south foothills of the Chinese Tian-Shan, along the edge of the Tarim massif. For the time being, even an approximation of Archean tectonics is difficult to conceive. Only the general features of the distribution of basic structures and that of younger structures, can be vaguely discerned.

Of a considerably wider distribution are the Proterozoic folds made up of very thick phyllite, mica schist, quartzite, amphibolite, marble, and schistose effusives. They are separated by a sharp angular unconformity from the overlying Lower Paleozoic carrying at its base Ordovician, Middle and Upper Cambrian beds. This hiatus may represent a long break between the close of the Proterozoic (?) and the onset of the Cambrian. However, the angular unconformity is not present everywhere. There are numerous instances indicating its lack of continuity. Locally-observed close connection between thick Proterozoic and Lower Paleozoic sections enabled V.A. Nikolayev, as early as 1928, to regard the Lower Paleozoic-Upper Proterozoic epoch as a single geotectonic cycle. Any arguments in principle, against that assumption are difficult [to] muster even now, in the presence of a kno[wn] unconformity between the Lower Paleozoic a[nd] the Precambrian. The question of the mean[ing] of Proterozoic folding in the Caledonids also remains open. As yet, the tectonic nature o[f] the vast Proterozoic schist zones is not cle[ar;] the majority of them may be regarded as Lower Paleozoic intrageosynclinal uplifts (intrageanticlines) maintaining their steady upward movement during all of the Lower (and Middle) Paleozoic. An example of that is the Sary-Dzhass subzone where Lower Paleozoic deposits, resting in a regional angular unconformity upon the Precambrian, are noted for their comparatively small thickness and simplicity of structural forms. Here also may belong the Atbashin horst, the Sonkul'-Tau and Kirghiz-Alatau exposures of crystalline schist, and certain crystalline schist belts in the East Tian-Shan.

The significance of the Precambrian relic structures in the Caledonian build-up was regarded by N.M. Sinitsyin as an important criterion in the subdivision of the Tian-Shan Caledonian folding into zones: Karatau-Talas, Susamyr, and Narat [14]. The westernmost, the Kara-Tau zone, is marked by extensive Precambrian development and a shallow depth of the Proterozoic structures. In the Susamyr zone, to the east, a plunge of the Proterozoic beds takes place with a corresponding decrease in the Precambrian expos[ure] area. East of Khan-Tengri, the Caledonids consist chiefly of intensely dislocated metamorphic schist and gneiss (Narat zone), ove[r]lain in sharp angular unconformity by Devonian or Lower Carboniferous deposits.

The plan of distribution for the basic elements of Proterozoic folding is in general accordance with that for higher structural stages. Deviations in the trend of individual structures, as locally observed, have no individual significance and do not go beyond similar anomalies in the Caledonian and Hercinian framework. The Proterozoic structures are characterized both by complex folds and simple forms (Makbal' anticline in the Kirghiz range, Kasan anticline in the Chatkal' range, and others).

CALEDONIAN STRUCTURE

The main feature of the stratigraphic section of the Caledonian folded province is the extensive distribution of its Lower Paleozoic, a sizable Precambrian development, and a subordinated position of the chiefly red, Middle Paleozoic deposits which form the upper structural stage in a discontinuous development [5, 6, 7, 11].

ı the Lower Paleozoic of the Caledonian cture proper, all stages of the Cambrian Ordovician have been recognized, repreed by thick, chiefly terrigenous deposits to a smaller extent, by carbonate and anic rocks. Their thickness is not unii, varying from zero to 5,000-6,000 m. one of the few examples of thin Lower ozoic zones may be mentioned the Saryıss subzone, formed under geanticlinal ozoic conditions.

'he Lower Paleozoic folded forms are ked by the complexity of their thick segts and by the simplicity of the thin ones. morphologic differences in the Caleian and Proterozoic folds are little known. tically, both are usually regarded as discrete structural stage [7].

'aledonian magmatic activity was marked he dominance of granitoids and the city and small sizes of basic and ultrac intrusions. Pre-Paleozoic, pre-Silurian, Upper Paleozoic granitoids are known.

'he main folding stage for this area falls ıe Ordovician-Silurian boundary. At that , the geosynclinal structure changed to ıticlinal. In the Silurian and Devonian area was subject to denudation, which sed a peneplanation of the Caledonian ed uplifts. The remnants of this most ent peneplain can be seen in various es of the Soviet and Chinese Tian-Shan.

'he Upper and Lower Upper Paleozoic ory of the Caledonids took different ses in their northern and southern segts. The northern Caledonids, embracing Ili and partially the Chu basins, undert subsidences over vast areas where k multi-colored sandstone, conglomerate, argillite with subordinate limestone e accumulated. Both acid and basic lavas red out from deep fissures along the es of these depressions. The sedimentaryanic fill of the epi-Caledonian depresıs, chiefly during the Early Carboniferous s with sharp angular unconformity upon oly-eroded Caledonian structures. In the er course of the Ili River, the dominant in the epi-Caledonian section is the er Devonian, also represented by a seditary and volcanic sequence. The young-Paleozoic rocks in these depressions ng to the Lower Permian. Thus, the cess of the development of the filled-up Caledonian basins embraces a very siz- period of time from the (Middle?) onian to the early Permian. The most nsive and general subsidences took place he Lower Carboniferous. The end of iment accumulation and folding did not ır simultaneously in all basins. The folds locally dated as Upper Devonian, Lower and Middle Carboniferous, and even Upper Carboniferous and Lower Permian.

The manner of folding in the Chu-Ili and other filled-up basins depends on the thickness and lithology of their components. As a rule, simple gentle folds, complicated by numerous faults, are typical.

The southern Caledonids are exposed in the Kara-Tau and Central Tian-Shan ranges, in the basins of the Talas, Naryn, and Tarim Rivers. In the Caledonids of this type, the filled-up Lower Paleozoic basins were not developed to any considerable extent. Here, the Middle Paleozoic mantle is rather thin, to spread over a small area, and is marked by a preponderance of red sandstone and argillite of the Lower Carboniferous. Of significance is a weak manifestation of volcanism, so very important in the filling of the northern-zone basins.

The Middle Paleozoic tectonic forms here are even relatively simpler: they are represented chiefly by gentle folds and monoclines of various forms, with comparatively rare steep folds observed only in the vicinity of block thrusts.

A suggestion has been made to name these two parts of the Lower Paleozoic folded province, the North and the South Caledonids [14]. Their boundary in the Chinese People's Republic runs approximately along the Tekes slope of the Narat range; in the U.S.S.R. it runs parallel to the latitude of Przheval'sk, as far as the Isayk-Kul Lake; farther west, it veers to the northwest to cross the Kungey and Trans-Ili ranges. Still farther west, it cuts the Chu-Ili divide, runs north of Malyy Kemin, and finally dips under the younger rocks of the foothills. The area of the filled-up Middle Paleozoic basin at the eastern terminus of the Kirghiz range, noted by the comparatively great thickness of its deposits, appears to be an element of the North Caledonids. This is the southernmost major structure in the system of epi-Caledonian basins.

The boundary between the Caledonids and the southern Hercinids is clearly marked by a zone of boundary faults, trending from the Kara-Tau range to the Przheval'sk meridian and farther into the Chinese People's Republic along the Aghiaz and Kok-Su Rivers, and the high mountain valleys of the Yuldusy. South of these faults, the Caledonian folding manifested itself only locally and was never of much significance in the geologic structure of the country; to the north of them, it was of primary significance, with the Hercinian folding subordinated. The Caledonids-Hercinids boundary was by no means a single structural line, as formerly supposed. Rather

it is expressed by a series of regional faults having a long period of activity, great depth, and en echelon disposition. In individual instances, large Caledonian blocks protrude into the southern Hercinids, splitting them into subzones. As an example, there is the large Sary-Dzhass structure, apparently making up a tectonic unit with the Atbashin horst. A similar "splitting-up" of the Hercinids, but on a considerably smaller scale, is observed along the middle course of the Naryn, in the area of the mouth of the Kokmeren River. To reiterate, the known instances of both the conformable and unconformable position of the Middle Paleozoic beds in the southern Hercinid branch, along their Caledonian boundary, are best regarded as local expressions of Caledonian folding, sharply decreasing in intensity south of that boundary.

The northern boundary of the Caledonian folded province (including the zone of epi-Caledonian basins) is traceable along the Baschiy-Konurulen valley, in the Dzhungara Alatau, then along the south slope of the Boro-Khoro ridge up to the high plains of the Bolshoy and Malyy Yuldusy, where it nearly joins the southern boundary of that province. Thus, the Caledonia province wedges out toward the Yuldusy high plains, and continues beyond and to the east, as a band 20 to 50 km wide. This wedge-like narrowing of the ancient body of the Tian-Shan is expressed in its orography as an abrupt approach to the northern and southern chains' which had originated on the ancient Hercinian basement.

HERCINIAN FOLDED PROVINCES

The Caledonids, making up the interior Tian-Shan ranges, are fringed on both sides by Hercinian structures which thus form two branches: the northern and the southern. The first is represented chiefly in the Chinese Tian-Shan; within the U.S.S.R. it appears only in the Dzhungara Alatau range. The second, on the other hand, is best developed in the territory of the U.S.S.R. The Hercinids usually present an assemblage of folded zones of different ages, having been formed in a number of Upper and Middle Paleozoic stages. Three distinct age groups are separable: 1) early Hercinian, with main folding at the close of Silurian -- beginning of Devonian time; 2) mid-Hercinian -- Lower and Middle Carboniferous; 3) late Hercinian, originating in the Upper Carboniferous and Permian [13].

NORTH HERCINIDS

The north branch of the Hercinian Tian-Shan structures takes in its peripheral northern ranges bordering on the Dzhungara plain. Here belong ranges of Dzhungara Alatau, Boro-Khoro, Uken, Dzharges, Bogdoshan', Karlyk, and the so-called Gobi Tian-Shan. This northern chain trends generally NW (N - 70° to 80° - W); it is about 2,000 km long, and 35 to 50 km wide; the highest summits of the main mountain groups reach up to 5,500 m.

During the Paleozoic, the north Tian-Shan branch was an area of subsidence and intensive sediment accumulation. Two main stages of subsidence and deposition are recognized in its history, separated by a period of uplift and folding. The first stage comprised the Ordovician and Silurian; the second -- Carboniferous and partly Lower Permian. The Ordovician and Silurian deposits are exposed exclusively in high mountainous areas, while the Carboniferous deposits are present nearly everywhere, forming the thickest and most complete sections only in the foothills.

The Ordovician is represented in the north Tian-Shan branch by a sequence of green-gray shale and sandstone, phyllitized to a considerable extent. Limestone is not typical of the Ordovician, being observed only in solitary intercalations.

Silurian deposits have a considerably wider distribution than the Ordovician, and exceed them in overall thickness. As a whole, the Silurian of the north branch presents an immense thickness of terrigenous, phyllitized, calcareous and siliceous shale with alternating quartz and graywacke sandstone. Its lower part carries numerous limestone beds. The middle part of the Silurian interval is taken over by porphyry and basic tuff.

The Ordovician and Silurian of the north Tian-Shan Hercinids is marked by intensive folding. The prevailing southerly dips suggest a tendency for a mass shift toward the Dzhungari massif.

Along the Dzhungara slope of the north Tian-Shan ridges, the early Hercinian folded complex is unconformably overlain by Upper Paleozoic marine beds. The age of the basal transgressive group changes toward the Dzhungara plain: in exposures near the high foothills, it is Middle Carboniferous; in lower foothills, it is Visean.

The main elements of the Upper Paleozoic section are as follows: Visean -- siltstone, sandstone, siliceous and calcareous shale with limestone beds (1,000 m thick); Middle Carboniferous -- limestone with shale and siltstone beds, changing upward to sandstone

ıd shale with occasional limestone; Upper ırboniferous -- sandstone and shale, locally ɔnglomerate, limestone, lava, and acid and ısic tuffs (up to 1,500 m thick). The Lower ɛrmian is developed locally over small ɛeas, being represented by multicolored ɔnglomerate, gray sandstone and argillite ıth limestone intercalations. The Upper ıleozoic section of the Dzhungara slope of ıe northern ranges is varied in facies. The ıanges are especially great along the trend ı the mountain system. For instance, there ı an easterly increase in volcanic and conıental formations, with a virtually comıete disappearance of the marine elements.

In the late Hercinian structure, the north ranch is a major asymmetrical anticlinorım, with the early Hercinian folded complex ı the highlands in its middle, and the Upper ıleozoic along the ridge slopes on its flanks. ıong its north limb, related to the Dzhunıra massif, the Paleozoic sediments are ɛry thick, being represented chiefly by arine facies; the folding is sharp with ɛrturning to the north. In the south limb ɔvince, adjoining the Caledonids, the same ɾrmations are much thinner and are marked ʳ a considerable content of volcanic and ɔntinental deposits and by fairly simple ɾrms of folding.

Among the most ancient folded structures the north Hercinid branch is that of the ɛntral part of the Dzhungara Alatau range, ıade up of thick sandstone shale and volınics, chiefly Devonian, resting either upon ɛcambrian crystalline schist and gneiss or ɔon Silurian schist. The intensely dislocated ɛvonian deposits are covered, with a sharp ıgular unconformity, by comparatively thin ɔwer Carboniferous beds. Thus, the early ɛrcinian folding plays the main part in the ɀhungara Alatau structure. This zone is ıaracterized by numerous small, steep ılds, trending latitudinally and complicated ʳ thrusts. It exhibits extended faults having ıng active periods, running both along the ɔundaries of the age zones and within them.

In the basins of the Lepsa and Tentek ivers, the northern foothills of the east ınge are built up by younger folding chiefly ɔncentrated at the Lower and Middle Carɔniferous boundary. It is represented by ɛep folds, trending longitudinally and made ɔ by Devonian effusives, shale, and sandɔne (up to 2,500 m thick); Lower Carbonerous effusives, tuff, sandstone, and shale ıp to 1,500 m thick); and Middle Carbonifɛrous sandstone and conglomerate (about 000 m thick). Going north, this structure ɾadually plunges under the young sediments ˸ the Balkhash-Alakul' depression.

The interior Dzhungara Alatau zone, between its north and south ranges, is located on an extension of later Hercinids from the Dzhungara slope of the Boro-Khoro range. The section in this zone begins with Tournaisian sandstone and shale (over 2,000 m thick). They are followed by Visean and Middle Carboniferous limestone and shale (up to 1,500 m thick) overlain by Upper Carboniferous conglomerate (up to 1,000-1,500 m thick) and effusives (locally up to 2,000-3,000 m thick). The folds and faults trend NE. Locally, the Middle Carboniferous conglomerate rests with sharp angular unconformity, upon Tournaisian, Visean, and early Middle Carboniferous deposits.

SOUTH HERCINIDS

The south branch of the Tian-Shan Hercinian folded province begins at the 92nd meridian and, gradually widening, extends westward over more than 2,000 km, as far as the Kyzyl-Kum plain. In the east, in the area of Lake Bagrach-Kul', it is a comparatively uniform, narrow (5 to 10 km) folded band, hemmed in between the ancient Tarim massif and the Tian-Shan's crystalline core. In the west, it is a vast complex of tectonic zones of different ages, about 500 m across its trend. It includes ranges of Khalyk-Tau, Kok-Shaal, Maydan-Tag, the region of the Kashgar mountain node, the Alay system, and the fanning-out western Tian-Shan spurs, in the basins of the Chirchik and Arys' Rivers.

The Paleozoic section here is marked by its fullness, even though not all of its elements are developed to the same extent. Most important are the Silurian, Devonian, and Lower Permian deposits; with subordinated Cambrian and Ordovician, also Upper Permian beds. Magmatic activity was present everywhere and in great variety. The largest and most numerous plutonic granitoids occur in the west Tian-Shan (including Alay); they are rare in the central and east Tian-Shan where late Hercinian granitoid intrusions predominate. Effusives are widely developed in certain Upper Paleozoic downwarps.

Structurally, the south Hercinid branch is better differentiated than the north. Early Hercinian, mid-Hercinian, and late Hercinian zones are recognized, locally in complex interrelationships [11, 13, 14].

The Early Hercinids extend in a wide belt along the south Tian-Shan ranges, from the meridian of Lake Lob-Nor to the Fergana ridge. Over the east segment of this belt they appear at a peripheral folded zone between the Caledonids and the Tarim massif. Farther on, the early Hercinid zone is

separated from the Tarim massif by a deep Mesozoic-Cenozoic downwarp and a wide zone of Upper Paleozoic structures. In the Khalyk-Tau range, the early Hercinid zone is marked by thick Devonian and Silurian beds. The first is represented by an alternation of shale, siltstone, and sandstone, also limestone locally in thick beds; the second, the more widespread, is represented by sandstone and shale with occasional limestone and thick lavas and tuff altered to greenstone. Over the body of the Khalyk-Tau range, the Silurian and Ordovician rest conformably; only near the Caledonian boundary, the base of the Silurian shows unconformities usually accompanied by arkosic sandstone and conglomerate.

The Ordovician and Silurian deposits of the Khalyk-Tau range are flexed by a system of steep folds definitely overturned and overthrust to the south, toward the Tarim massif. The Middle Devonian rests upon this complex in a regional unconformity.

The Middle and Upper Paleozoic in the Khalyk-Tau range are developed along its Caledonid boundary (Khaydyn-Gol' zone) and along the Tarim massif (Maydan-Tag zone).

Two sequences are developed in the Khaydyn-Gol' zone, connected by transitional beds: the lower, consisting of sandstone and shale and assigned to the Upper Silurian; and the upper, consisting of limestone and assigned to the Middle and Upper Devonian. At the sources of the Khaydyn-Gol', the thickness of the Devonian limestone reaches 1,500 m, but decreases to 300 m, southeast of there, with red marl, and conglomerate appearing among the limestones.

The Khaydyn-Gol' Devonian beds remain comparatively undisturbed, forming broad, gentle folds, with dips along their flanks from 20° to 35°; only in the vicinity of faults do the dips steepen and commonly change their direction.

An immediate westerly extension of the Khalyk-Tau structures is the so-called Kok-Shaal zone of late Devonian folding, embracing a part of the Kok-Shaal range. According to recent ideas, this zone extended over all of the range and its spurs. However, the latest study by the Kirghiz Geological Administration and the All-Union Geological Institute (VSEGEI), has proved a wide occurrence here of pre-Veisean folding and a localization of the early Hercinian folding. The westernmost spurs of the Kok-Shaal in the lake Chetyrkul' basin consist chiefly of thick Silurian shale and -- to a smaller extent -- of Devonian deposits.

Beside the Khalyk-Tau and Kok-Shaal, the early Hercinian folding is also expressed in the southeastern Tian-Shan spurs, sometimes united into a separate mountain system called the Alay or Hissar-Alay. Two early Hercinian zones of folding are separated within the Alay system: the Zeravshan and the Kshut. The first includes the ranges of Nuratin, Turkestan, and part of the Zerav shan and Zirabulak-Zyaddin Mts. [13, 14]; the second takes in sizable portions of the Zeravshan and Hissar ranges.

The Zeravshan zone is represented chiefly by a thick Silurian flysh-like formation (3,000 to 4,000 m thick). Cambrian, Ordovician, Devonian, and Carboniferous deposits are poorly developed here. A characteristic tectonic feature of this zone is small, steep folds in shale, without regular orientation. The Devonian age of the Zeravshan folding is indicated by the Visean beds resting upon various Silurian and Devonian layers.

The Kshut zone differs from the preceding one in the structure and composition of its components, and in the somewhat younger folding. The Devonian of this zone, represented by terrigenous and carbonate facies, rivals the Silurian in its thickness, with the deposits of other systems lacking. A peculiarity of the Kshut zone is its scaly structure, characterized by a regular alternation of wedges of thick limestone and shale. Early Hercinian folded formations are known from the Fergana ridge and the associated Alay spurs, but here they are rather poorly developed and partly camouflaged by later dislocations.

The general features of early Hercinian folding are: a preponderance of terrigenous Silurian and Devonian deposits throughout its section, in the Soviet Tian-Shan, and of the Silurian and Ordovician in its Chinese portion; a lack of a clean-cut relationship between the facies zonation of the sediments, the major structural forms, and the loci of a strictly regular orientation of folds in individual zones; a single stage zone structure; and a comparative paucity of intrusive phenomena.

The Mid-Hercinian zones. This name is given to the regions of folding originating in the Lower and Middle Carboniferous. Here belong the Chatkal' and Kavak zones, also a zone of high foothills along the north Alay slope. Main stratigraphic elements in the section of these structures are the Devonian and Lower and Middle Carboniferous deposits, whose relative importance varies from region to region. Moreover, Silurian, Lower Paleozoic, and Precambrian

rystalline schist exposures are locally wide-pread. The Chatkal' zone embraces the anges of Chatkal', Pskem, partly Ugam, toynak and Fergana; the Kavak zone unites ie mountain structures of the middle course of river Naryn (Moldo-Tau, Naryn-Tau, okiyrim-Tau, and others). The stratigraphic ection of these zones opens with Lower aleozoic deposits, comprising the Ordovi-ian and Cambrian. According to latest data, ie Silurian here is poorly developed and ather thin. The Middle Paleozoic usually egins with Devonian multicolored sandstone, hanging to thick Upper Devonian -- Lower arboniferous limestones. The Lower Car-oniferous of the Kavak zone contains an qual share of the terrigenous and carbonate icies. The Middle Carboniferous is similar i its makeup. The Upper Paleozoic is eveloped along the periphery of the Chat-al' zone and is lacking in the Kavak zone.

The folding in the Chatkal' zone is ex-ressed in brachianticlines trending north-ast and complicated by faults. The Kavak one is marked by latitudinal, mostly plate-ke structures and by an abundance of iults.

Younger, late Middle Paleozoic linear olds and plates of a latitudinal trend pre-ominate in the high foothills of the north lay slope. The plates are especially num-rous in the north foothill belt. This zone xhibits a distinct relationship between the liddle Paleozoic change in facies and thick-ess, and its structural forms: anticlines arry "incomplete" sections, chiefly of errigenous deposits, rather thin and with races of long sedimentary breaks; synclines re associated with stratigraphically fuller nd thicker sections, chiefly of carbonates. ther mid- and late-Hercinian folded zones re not observed to carry similar changes n the same scale.

The Late Hercinian zones. The Upper aleozoic movements terminated a long rocess of development of a Paleozoic Tian-han geosyncline and initiated its change to folded province. The Upper Paleozoic evelopment is marked by a differentiation f the geosyncline into a system of down-arps and uplifts, expressed in the topogra-hy. The filling-up of the downwarps every-here is characterized by an abundance of oarse clastic beds, with a preponderance f local material and in places, by immense ccumulations of pyroclastics (downwarps of outh Hissar, Karzhantau-Kuramin, and orth Pamir zones). All Upper Paleozoic ownwarps are distinguished by their indi-iduality, as demonstrated by the difference n their respective sections, at the time of heir folding; in the number and relative ignificance of their angular unconformities, in their tectonics, magmatic activity, and metallization. It should be noted that the main mineral wealth of the Tian-Shan is connected with these late Hercinian tectonic movements.

The processes of sedimentation, folding, and orogeny -- gradually diminishing in intensity -- cease toward the close of the Permian. Simultaneously, the Hercinian surface was gradually leveled off, to become a peneplain. Thus, the Hercinian folding ended not with the appearance of lofty mountains but rather with the formation of a denuded plain -- a peneplain -- as demonstrated for the West Tian-Shan, by N.M. Sinitsyn, in 1947.

The late Hercinian folding in the south Tian-Shan branch is represented by the South-Hissar, Surmetash, Kara-Chatyr, Karzhantau-Kuramin, Dzhamandavan, and Maydan-Tag (Aksay) zones, all formed in the Upper Carboniferous and Permian; also by contemporaneous block forms in the areas of uplift, not considered in this paper.

The South-Hissar zone is marked by a wide distribution of thick Middle and Upper Carboniferous clastic and pyroclastic beds, pierced by Upper Carboniferous-Lower Permian granitoids.

The as yet little-known Middle Paleozoic deposits are represented by thick, sparingly fossiliferous Silurian, Devonian, and Lower Carboniferous shale and limestone. The Middle Carboniferous includes basic effusives and tuffs, with associated sandstone and limestone (total as much as 1,500 m thick). They are succeeded by Upper Carboniferous sandstone, shale, conglomerate, tuff, and basic effusives (1,000 m thick), overlain unconformably by the upper volcanic sequence of basic and intermediate effusives, tuffs, tuffobreccia, conglomerate, and sandstone (up to 1,000 m thick). The Paleozoic section is crowned by a nearly horizontal series of red sandstone, clay, and conglomerate, tentatively assigned to the top of the Permian and differing but little in degree of consolidation, from Mesozoic and Cenozoic rocks.

The Upper Carboniferous and Permian deposits are marked by their flat dips, in contrast to the sharply dislocated ancient series.

The Surmetash folded zone was formed during the Permian, in a downwarp filled up with thick Middle and Upper Carboniferous shale, sandstone, conglomerate, and to a smaller extent by Permian sandstone and conglomerate. The overall thickness of the Upper Paleozoic in the Surmetash downwarp reaches 4,000 m.

Within this zone, the Upper Paleozoic rests in a variety of relationships to the underlying Middle Paleozoic: in some places, a gradual transition between the two is observed; in some others, there are considerable angular unconformities and an evidence of profound stratigraphic breaks.

Its folded forms are sharp (on the south slope and divide part of the Alay range), elsewhere very simple and gentle. The time of main folding occurred between the Early and Late Permian. Geographically, the Surmetash zone belongs to the highland part of the Alay range and to the west slope of the Fergana range.

The Kara-Chatyr zone is located in South Fergana, in the lowest north Alay and Turkestan range foothills; it is overlain to a considerable extent by Mesozoic and Cenozoic deposits.

A distinguishing feature of its section is the great (3,700 m) thickness and terrigenous character of its Upper Paleozoic sequence (Middle Carboniferous, Upper Carboniferous predominating, and Lower Permian) and a lack of magmatic rocks. A major unconformity separates this complex from the Middle Paleozoic, represented by rare exposures of the Cambrian, Silurian, Devonian, and Lower Carboniferous deposits.

The Upper Paleozoic folding is expressed in rather gentle flexures; the broad and gentle Tuleykan syncline should be noted in this connection because of the nearly horizontal beds in its central part.

The Karzhantau-Kuramin zone includes the westernmost Tian-Shan spurs, from Fergana to the basin of the Arys' River, in the north. It is noted for the generally meridional trend of its structures, formed by very thick and diversified Upper Paleozoic volcanics [3]. The more ancient deposits are subordinate to them. The lower structural unit is made up of Lower Paleozoic rocks (shale exposures are rare); sandstone, limestone, and effusives of Middle and Upper Devonian and Lower Carboniferous age. The thickness of the Middle Paleozoic appears to be great in certain sections, reaching 2,500 m.

The upper structural unit is represented by Upper Paleozoic rocks. There is a striking abundance of pyroclastic accumulations among them, of immense thickness (up to 6,000 m) and broken by a number of unconformities. The presence of Upper and Lower Carboniferous and Lower Permian deposits has been established. One school of thought recognizes Upper Permian here, and even elements of the Lower Triassic [3]. The intrusive magmatism was very diversified. Caledonian and non-contemporaneous Hercinian granitoids are known to be present. The volcanic beds are flexed into simple forms accompanied by numerous faults.

The Dzhamdavan-Tau zone, located within a ridge of the same name, consists exclusively of thick Carboniferous deposits. The Upper and Lower Paleozoic within it are dislocated together, thus forming a single structural unit. The stratigraphic section of this zone, with the exception of the problematical presence of the Ordovician, begins with Upper Devonian red sandstone and overlying limestone (200 m thick). Higher up, there are Tournaisian limestones (500 to 1,500 m thick), assorted Visean limestones (as much as 1,800 m thick), Namurian sandstone and limestone (0 to 900 m thick), then a thick, chiefly sand and shale Upper Carboniferous sequence (3,500 m thick). The Lower Permian is made up by sandstone, conglomerate, and effusives, resting apparently unconformably upon more ancient beds. The structure of this zone is marked by large, steep, symmetrical folds, trending NE; faults are inconspicuous. Magmatic formations are of a negligible development.

The Maydan-Tag zone. A large zone of Upper Paleozoic folding runs along the Tarim massif boundary, taking in the ridges of Maydan-Tag and Kara-Teke, also the south foothills of the Khalyk-Tau. It is subdivided into two subzones: the Maydan-Tag proper, adjoining the early Tian-Shan Hercinids and characterized by the development of a flysh sandstone and shale complex, Middle and Upper Carboniferous in age, and about 4,000 m thick; and the Muzduk, bordering on the Tarim massif, having a predominantly carbonate sequence not over 1,200 m thick and comprising all of the stratigraphic horizons, from the Visean up to and including the Lower Permian. The boundary between the two zones is a fault zone where the sand and shale complex grades rapidly into contemporaneous limestone. Along the Tarim massif boundary, the Muzduk limestone, in their turn, is replaced by contemporaneous limestone, sandstone, and marl of the Kel'pin facies; their thickness, despite their large stratigraphic span (from Visean to and including Lower Permian), does not exceed 250 m. The change from the Muzduk Upper Paleozoic section to the Kel'pin type likewise occurs in the narrow fault zone which is the northern boundary of the Tarim massif.

The sandstone and shale Maydan-Tag complex forms systems of small asymmetric folds, uniformly tilted to the south. In the Muzduk subzone, the Upper Paleozoic limestone, together with the underlying Lower

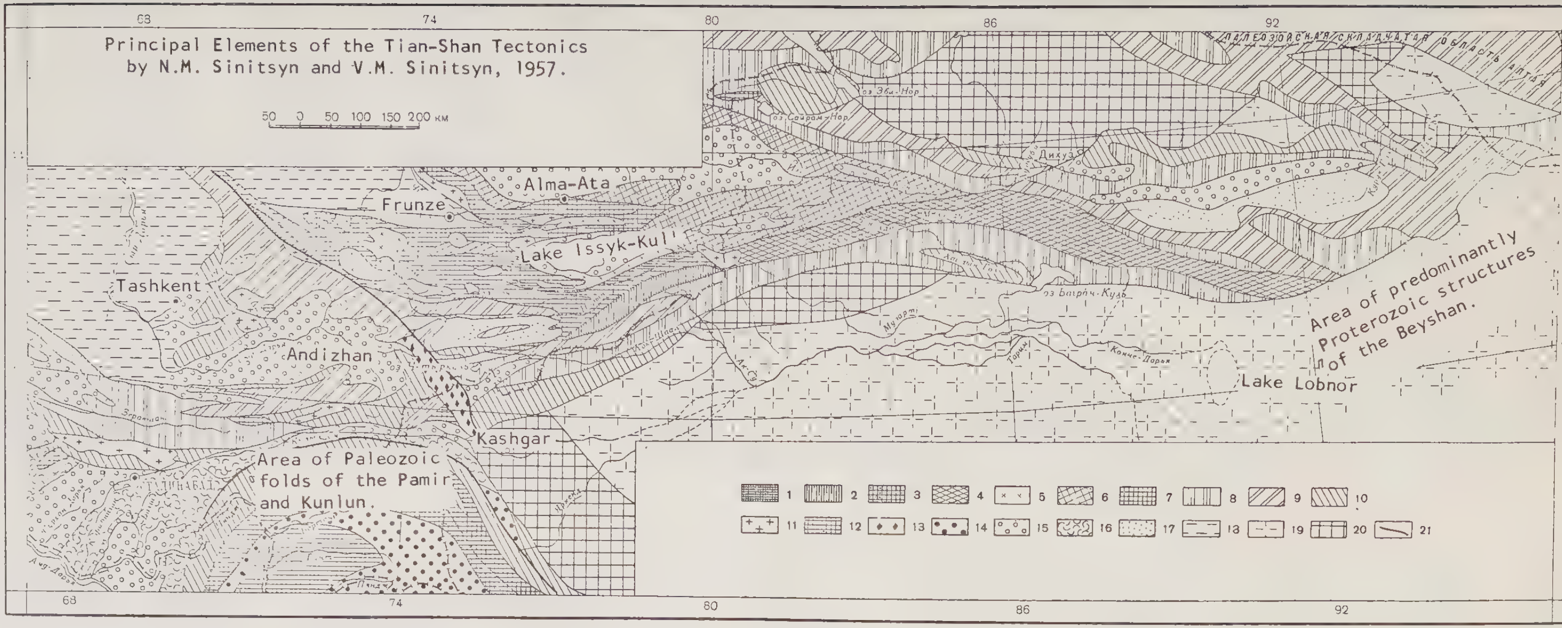

Fig. 1. Principal elements of the Tian-Shan tectonics (by N.M. Sinitsyn and V.M. Sinitsyn, 1957)

I. Caledonian folded province. 1-Proterozoic and Archean (?) formations of the central massifs and Caledonian anticlinoria; 2-zones of gently folded Lower Paleozoic; 3-zones of Caledonian folding; 4-Undifferentiated zones of Caledonian and Precambrian folding; 5-Caledonian and older granitoids (in West Tian-Shan); 6-epi-Caledonian Middle Paleozoic structures.

II. Hercinian folded province. 7-Precambrian formation of the central massifs and Hercinian anticlinoria; 8-early Hercinian folded zones; 9-mid-Hercinian folded zones; 10-late Hercinian folded zones; 11-major plutonic Hercinian granitoids of West Tian-Shan.

III. Mesozoic and Cenozoic structural elements. 12-Precambrian formations of the central massifs in the Mesozoic folded province; 13-Mesozoic folded zones; 14-pre-Cretaceous folding of the South Pamirs; 15-intermontane and frontal depressions filled (chiefly along their rims) with gently dislocated thick Mesozoic and Cenozoic deposits; 16-Cenozoic folded zones; 17-intermontane and frontal basins filled with gently dislocated and undisturbed, chiefly Cenozoic deposits (Cenozoic block uplifts of the mountain ranges are not shown on map); 18-provinces of mantle-like distribution of the Mesozoic and Cenozoic over frontal plains (epi-Caledonian and epi-Hercinian platforms).

IV. Stable massifs. 19-provinces of shallow, crystalline basement, locally exposed; 20-provinces of deep downwarps in the crystalline basement, filled with gently dislocated thick Mesozoic and Cenozoic deposits; 21-Talas-fergana and North Pamirs boundary faults.

Carboniferous deposits, form large box-like folds; approaching the Tarim massif, the limestone folds become more complex, grading into steep asymmetric forms, tilted southward farther on.

A special place in the structure of the south Tian-Shan Hercinids belongs to the Kashgar node where the northeastern Alay structures come together with those of the northwestern Fergana range. The center of the node is taken over by the Suluterek massif, representing a high in the Precambrian metamorphic basement (see Fig. 1).

The youngest of the Paleozoic structures are the small "remnant red moulds" of the Paleozoic downwarps, filled with gently dislocated, or horizontal, thin Permian beds closely resembling Mesozoic deposits (Khanakin series of the South-Hissar downwarp, Madygen series of south Fergana, Nadak series of the Kuramin range spurs, and others). They were not affected either by folding or by Permian denudation to any great depth. The topographic surface of such moulds is more or less parallel to the horizontal beds; genetically, it approximates a structural plain [13].

The structure of these moulds graphically illustrates the gradual dying down of the Tian-Shan geosynclinal conditions and its gradation to a stable development which persisted from the close of the Permian until the Neogene.

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Leningrad State University
Coal Geology Laboratory,
U.S.S.R. Academy of Sciences

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CONTINENTAL CENOZOIC DEPOSITS IN BAIKAL TYPE BASINS

by

N. A. Logachev

ABSTRACT

Throughout the Sayan-Baikal highlands, Cenozoic sedimentation is separated from the Mesozoic, both in space and in time. This paper offers the first regional stratigraphic classification of Cenozoic deposits for the Baikal type basins, and discusses the ancient weathering processes. Sediment accumulation occurred in stages differing in tectonics, relief, and climate. The stratigraphic zonation of autochthonous formations, reflecting a chemical differentiation in the course of time, is determined by the process of chemical weathering of the crystalline basement silicates in the source areas.

* * * * *

An analysis of the papers bearing in one way or another on the interesting problem of the origin of the Baikal basins, shows that the attention of geologists has been concentrated mainly on the tectonic aspect of these recent subsidences, on the evaluation of the effects of faults and downwarps on their structure, and on the general causes of morphogenesis of the folded mountain belt fringing the south spur of the Siberian Caledonian platform. It may be stated without exaggeration that definite results have been achieved in the study of the Mesozoic and Cenozoic tectonics of the Sayan-Baikal province. A lengthy discussion on the origin of Baikal and of inland depressions associated with it both spatially and genetically, however inconclusive, has been and still is fruitful in the working out of regional and general problems of Mesozoic and Cenozoic tectonics [4, 5, 8, 9, 14]. At the same time, the study of the composition of the rocks filling the Baikal type basins is lagging. The purpose of this paper is to close this gap, to a certain extent, and to compensate, however partially, for the onesidedness in the study of Cenozoic history of the Sayan-Baikal highlands.

1. STRATIGRAPHY OF CENOZOIC DEPOSITS

The Cenozoic deposits of the high Trans-Baikal rest in basins, in sharp unconformity with a strongly dislocated basement of metamorphic and effusive Precambrian and partly Lower Paleozoic rocks. Only in a few depressions are lenses of Cenozoic deposits separated from the ancient crystalline basement by thick, continental Jurassic deposits whose small "shreds" have escaped erosion. There must have been a long hiatus between Mesozoic and Cenozoic sedimentation, embracing a period from the Early Cretaceous to the Neogene, because no definite Paleogene and Upper Cretaceous deposits have been found on the Sayan-Baikal arched uplift. Nor is there any reason to assume, with N.V. Dumitrashko, their buried presence in the south Lake Baikal basin, on the basis of his idea of a continuous development of this basin, beginning with the Middle Jurassic [1]. Wherever deep wells penetrate the sedimentary section of the basins and the crystalline basement, no Mesozoic deposits have been found.

The basement, or its weathered crust, is in contact with lower Neogene clay, siltstones, and sandstone. An exception is the Selenga flank of the South Baikal basin where a thick Jurassic wedge, coming sublatitudinally from the direction of Khamar-Daban, enters between the basement and the Neogene deposits (Fig. 1); this wedge, according to N.S. Shatskiy [16], passes under the lake to join the Irkutsk Jurassic. The presence of fairly thick contiguous Cenozoic and Mesozoic deposits is noted in the Kalar and Charsk, as well as in individual basins of the West Trans-Baikal. In the latter, the

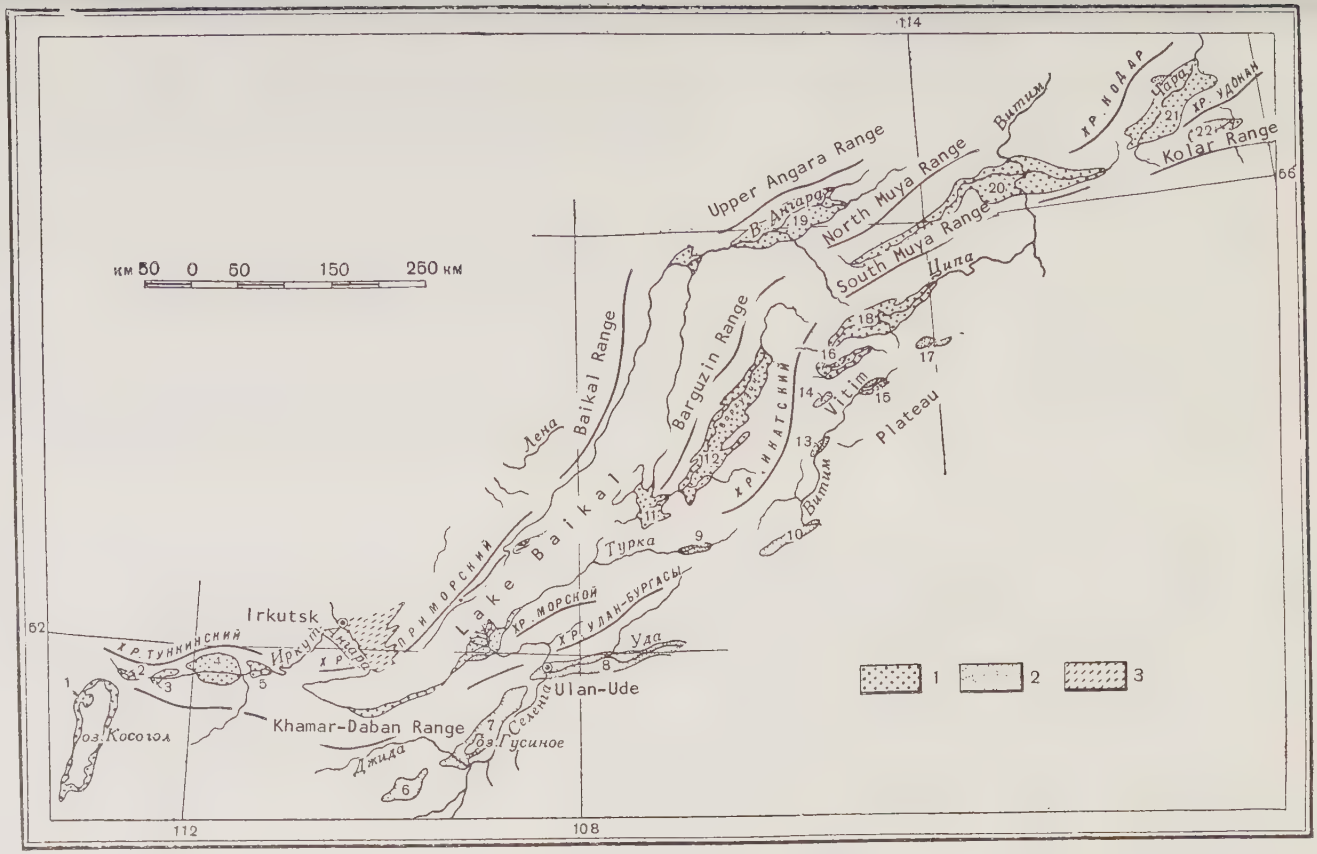

Fig. 1. Distribution of non-contemporaneous continental deposits in Trans-Baikal basins.

1-Neogene-Quaternary deposits of Trans-Baikal type basins; 2-Middle Jurassic-Lower Cretaceous deposits of Trans-Baikal basins; 3-Middle Jurassic deposits of the Irkutsk amphitheatre.

Basins: 1-Kosogol'; 2-Mondin; 3-Khoytogol'; 4-Tunkin; 5-Torsk; 6-Borgoy; 7-Gusinoozersk; 8-Udin; 9-Turkin; 10-Zazin; 11-Yst'-Barguzin; 12-Barguzin; 13-Tilim; 14-Gorbylok; 15-Verkhne (Upper) Chininsk; 16-Tsipikan; 17-Toloy; 18-Bauntovsk; 19-Verkhne (Upper) Angara; 20-Muya; 21-Charsk; 22-Kolar.

thickness of Cenozoic deposits is tens of times smaller than in the Baikal type depressions, with the magnitude of the Paleogene-Upper Cretaceous hiatus persisting. These facts, together with the studies of the last 5 years, confirm the original idea of Ye. V. Pavlovskiy that the formation of the Baikal-type basins took place after the Mesozoic sedimentation, and that there had been no succession in the development of the Mesozoic (Trans-Baikal) and Cenozoic (Baikal) basin such as Ye. A. Presnyakov assumed on the basis of juxtaposition and considerable external similarity in structure [7, 11].

It may be stated that the Cenozoic sedimentation stands generally apart from the Cenozoic not only in time, because of a regional break in sedimentation during the Late Cretaceous and Paleogene, but in space as well, because of a migration of Cenozoic tectonic activity toward the edge of the Siberian platform. Only locally did the belt of major Cenozoic subsidences pass through Mesozoic structures, but the effect of the latter on the direction and dimensions of the Cenozoic depressions appears to have been largely passive. The assumption of an indirect connection between the Mesozoic and Cenozoic basins finds substance in a lack of Mesozoic deposits at the bottom of such Baikal system basins as the Tunkin and Barguzin; in the crossing, in the Selenga delta, of a latitudinal Jurassic downwarp, by the Cenozoic South-Baikal basin; finally, in the faulting of the Jurassic by the basin boundary faults [6, 7].

In many places, traces of a weathered crust have been preserved at the base of the Cenozoic section. According to deep drilling data, from the Barguzin and Tunkin basins and the Selenga delta, red clays usually lie at the base of the Tertiary; they consist mainly of hydromicas, kaolinite, and other weathering products. The weathered crust is best preserved in exposures along the Baikal shores. Thus, according to G. Ye. Ryabukhin and G.B. Pal'shin, a basal clay bed, as much as 80 m thick, lies between the Tertiary coal measures and the Khamar-Daban Precambrian, in the area of Tankhoy station, between the Selengushka and Malaya (Little) Yazovka Rivers. On petrographic evidence, the lower part of this clay, contaminated by weathered fragments of the basement rocks, is regarded as a product of subaerial weathering.

On the Malomorsk shore of Lake Ol'khon, according to Ye. B. Pavlovskiy, a weathered crust has been preserved in the centers of basins filled with arenaceous and argillaceous Tertiary deposits; it is a zone of vividly-colored clay formations with stringers of phosphatic carbonate, oxides of manganese, iron, etc. Monothermite, kaolinite, and beidellite are the predominant minerals in the clays. The thickness of the weathered crust locally exceeds 10 m; at the base, it grades into Archean crystalline schist and gneiss.

The Barguzin basin weathered crust, as identified recently by V.V. Lamakin near Alga village, is developed chiefly on granite and reaches a thickness of 3 m and more. It appears that only the "roots" of a former and thicker weathered zone have been preserved here. Unquestionable remains of a weathered crust are present on the Vitim plateau where, according to S.G. Mirchink, A.I. Grigor'yeva, and S.D. Sher, they have been locally preserved underneath a Pliocene alluvium. The composition of the weathered crust changes depending on the substratum. Granite weathering products -- red-brown clays filled with angular fragments of quartz and weathered feldspars, are characterized by an obvious preponderance of the clay, also by their high composition of weathering products -- beidellite, montmorillonite, cerlite, kaolinite. Some evidence of Tertiary weathering were noted by N.A. Florensov in West Trans-Baikal, and by A. Kh. Ivanov in East Prikosogol'.

Thus, despite the fact that no particular attention has been paid to the problem of ancient weathering, new studies begin to reveal the remains of a weathered crust. Prior to the Neogene, and at its onset, conditions were favorable for chemical weathering. A mantle of weathered rocks covered a vast area of the pre-Neogene surface, slightly uplifted and with a poorly developed topography; however, the weathered areas were subsequently restricted to the basins which had not been expressed in the relief developed by weathering. At the very beginning of the Neogene, the areas of weathering of the crystalline basement considerably contracted because of the many large and gentle depressions which were initiated on the sites of future Baikal type basins and the first batches of material carried down the neighboring gentle slopes began accumulating. An intensive chemical weathering was taking place along these slopes, during the Miocene and Lower Pliocene; it was interrupted in the second half of the Pliocene, by mighty tectonic movements and the advent of a cooler climate.

On the basis of faunal material, but most particularly on lithologic facies features of the section, the following regional Cenozoic stratigraphic scheme is proposed:

1) Coal-bearing formation (Miocene and Lower Pliocene).

2) "Ochre" formation (Upper Pliocene).

3) Tuffaceous-sedimentary formation per Pliocene-post-Pliocene).

4) Sandy formation of Middle (?) and ːer Pleistocene.

5) Latest deposits (Holocene).

The thickness of individual formations, and overall Cenozoic thickness within the ins, increases many times with approach the center of major basins. The maximum wn thicknesses are distributed as follows, ng the Sayan-Baikal arch: The Tunkin in, about 2,500 m; the Baikal basin, in nt of the Selenga delta, over 3,500 m; Barguzin, about 1,700 m. The maximum ement subsidence took place in the south kal basin. In all depressions, almost a f of the total Cenozoic thickness is made by the lower member of the section -- Miocene-Lower Pliocene coal measures. e other members, with the exception of n Holocene patches, differ but little in ir thickness (in meters) (Table 1 and . 2).

A brief description of individual forma-ns is given below.

The coal measures consist of clay, silt-ne, and sandstone, with layers and lenses fresh water marl, chemically precipitated rbonates, contaminated more or less by rigenous material; diatomaceous clay, tomite, and brown coal. Their assign-nt to Miocene and Lower Pliocene is sed on findings of warmth-loving molluscs, the South Baikal basin, in the area of nkhoy station [3]. This dating seems to be nfirmed by the remains of vertebrate mam-als found by A.F. Kitaxnikov in alluvial ay and silt with beds of brown coal, cov-ing the weathered core, along Ol'khon ver. L.N. Ivan'yev and A.G. Yegorov entified here the remains of a small and large turtle, large adder, slime-loving h, and ancestors of shad and salmon. The ssiliferous rocks also contain a rich pol-n spectrum, primarily of warmth-loving, oad-leaf forms: hazelwood, alder, maple, m, holly, linden, beech, oak, liquidambar, t trees, and myrtle.

The pollen spectra of the coal measures the Tunkin, South-Baikal, and Barguzin sins, and the basin of the Vitim plateau, e similar. In these regions, M.A. Sedova, I. Il'yasova, L.N. Gutova, and other leontologists also have found a sizable llen content of annual species: hornbeam, zelwood, nut, hickory, lapina, beech, oak, estnut, maple, elm, hop hornbeam, alder, mach, linden. Not uncommon in the spectra are the representatives of subtropical vegetation: myrtle, laurel, magnolia, holly, and nyssa (up to 8 percent in individual samples). The warm climate forms become scarce at the top of the coal measures, both in their generic and numerical content.

Among the main lithologic features of this formation are the following: first, the paramount importance of arenaceous and argillaceous sediments (gravels are clearly subordinate, while conglomerates are very inconspicuous); second, a fairly steady granulometric composition in section, showing that the present proximity of the mountain ridges had no appreciable effect on the mechanical composition of the coal measures. Moreover, an important feature of the Miocene-Lower Pliocene deposits is their relative wealth in organic matter (brown coal, diatom algae), with the coal beds, diatomite, and diatomaceous clays gravitating toward the edges of the formations. In the central parts of the basins, where the formations thicken, carbonaceous plant remains are either scattered throughout the section or else form only thin intercalations of brown coal, as much as 15 cm thick. Diatom algae, which acquire a rock-forming significance in localities along the basin periphery, are represented by assemblages of fresh water plankton forms and of shallow bottom growths. Among autochthonous components, beside common opal diatom tests, there occur carbonates of calcium and magnesium. The latter enter the composition of marl or, less commonly, form intercalations of chemically precipitated carbonates, as much as 1.5 m thick. Autochthonous iron compounds are represented chiefly by ferrous varities -- pyrite and vivianite -- in small amounts. The formation as a whole is marked by its high organic carbon content, locally as much as 8 percent.

In the Southwest Trans-Baikal, the coal measures' deposition was accompanied by large outpouring of basalt lavas, with the center of effusive activity in the Tunkin basin, in the area of deepest burial of the crystalline basement [2]. Here, the basalts occupy almost a third of the section (Fig. 3-A), in layers from several to 80 m thick (in cases of great thicknesses, it is possible to drill through several flows or through sills and steep veins). Volcanic landscapes were a feature of the Southwestern Trans-Baikal of that and later times. Inasmuch as basalt and pyroclastics of similar composition make up all of the Tunkin Cenozoic section, it is proper to regard the Tunkin basin as a volcanic-sedimentary complex (Fig. 4).

The overlying "Ochre" formation is

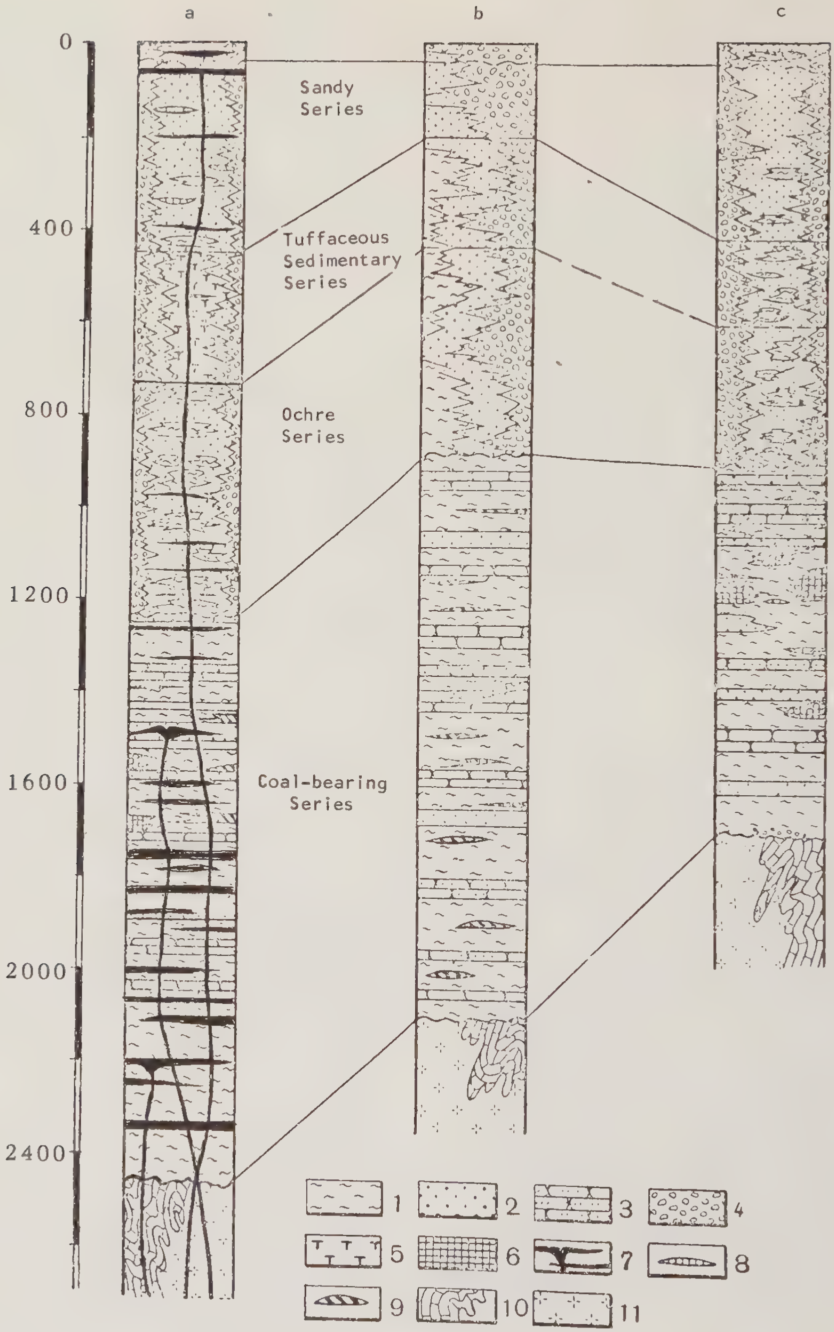

Fig. 2. Correlation of Cenozoic sections in Tunkin basins (a); Southeast shore of Lake Baikal in the vicinity of Tankhoy (b); and Barguzin basin (c).

1-clay, siltstone, silt; 2-sand; 3-sandstone; 4-conglomerate, pebble beds, breccia, gravel sand; 5-tuff, tuffite; 6-diatomite, diatomaceous clay; 7-basalt; 8-peat; 9-brown coal; 10-Precambrian metasediments; 11-Precambrian meta-igneous rocks.

Table 1

Series	Tunkin Basin	Baikal Basin (Selenga Delta)	Barguzin Basin	Vitim Plateau
Sandy	440	600	400	200
Tuffaceous Sedimentary	300	400	200(?)	Ancient alluvium of Pliocene terraces
"Ochre"	480	700(?)	300	
Coal-bearing	1250	1800	800	100

parated from the coal measures by an rupt change in the mechanical composition its sediments, and by an apparent uncon-rmity. The change in the mechanical com-sition is very distinct along the edges and comes less so toward the center of the sins. The main feature of this formation a preponderance along the periphery of e depressions, of coarse conglomerate, eccia, gravel and coarse sand; in the ntral parts, they change in facies to sand, lt, even clay (Fig. 3). Another feature of e "ochre" formation is its greater satura-on with iron hydroxyls, both diagenetic and rrigenous. Iron hydroxyls are present in ssorted concretions, crusts, leached flows, dmixture to cement, and in individual rains left behind in the diagenetic process n this case, limonite grains are disinte-rated, giving off streamers of brown iron ydroxyls, suggesting their incipient solu-on). The amount of Fe_2O_3 is not constant ut varies from place to place, from 4 per-ent to 35 percent by weight. Of importance s the presence of rock fragments deeply ltered by chemical weathering.

Beyond the Trans-Baikal basins, our nowledge of Pliocene deposits is still poor; owever, in a study of placer gold deposits the Vitim plateau, S. G. Mironchik and thers have found alluvium associated with ncient and modern valleys locally resting a weathered crust and saturated with eathering products and weathered frag-ents of ancient crystalline rocks. Its oarseness suggests a high differentiation the relief of its source. These features ake it possible to correlate the ancient itim plateau alluvium with the "ochre" rmation of the Baikal basins.

The next member of a normal section is e Upper Pliocene-post-Pliocene tuffaceous-sedimentary formation. A specific feature of this period was explosive volcanic activity, especially intensive throughout the Tunkin chain of basins. The tuffaceous sedimentary formation of the Tunkin basin proper consists of diversified basalt tuff, tuffite, tuffitic sandstone, all changing in facies to normal sedimentary terrigenous material, toward the Nilov spur and Tunkin ridge.

Thus, part of the pyroclastics are different even within a single basin. In the South-Baikal basin, to the east, tuffaceous rocks are not recognized; however, even there a mineralogic analysis of correlative rocks has identified basic volcanic glass

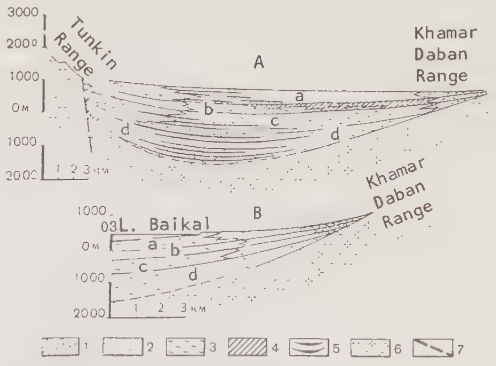

Fig. 3. Distribution of principal rock types in a Tunkin basin cross-section (A) and that of southeastern shore of Lake Baikal (B)

Series: a-sandy; b-tuffogenous-sedimentary; c-"Ochre"; d-coal measures; 1-conglomerate, pebble beds, breccia, gravel and sand; 2-sand, sandstone; 3-clay, silt, siltstone; 4-tuff, tuffite; 5-basalt; 6-Precambrian crystalline basement; 7-Tunkin normal fault.

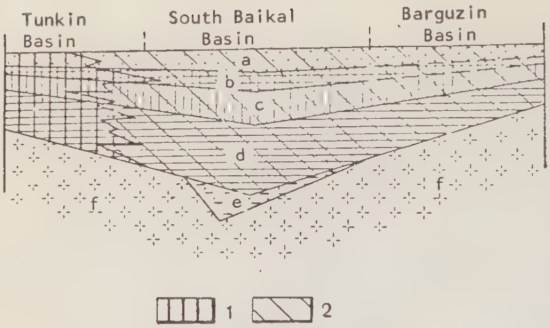

Fig. 4. A scheme of stratigraphic and facies relationships within the Cenozoic section along the Sayan-Baikal arch.

1-volcanic-sedimentary formations; 2-sedimentary formations; a-sandy formation; b-tuffaceous-sedimentary formation; c-"Ochre" formation; d-coal measures; e-Jurassic deposits; f-crystalline basement rocks.

(up to 11 percent of the light fraction). It does not matter how this glass came to be in that basin -- whether from the widespread post-explosive material of the Tunkin volcanoes or from the disintegration of local pyroclastic formations; a correlating significance of the basalt glass (emphatically, glass and not basalt itself, because the outpouring of the latter was spread throughout the Cenozoic) is not to be doubted.

In the Barguzin depression, pyroclastics are not known from the deposits of that time; nevertheless, the tuffaceous-sedimentary formation, being connected by uninterrupted deposition both with the underlying and the Quaternary section proper, is of a regional distribution. Local differences arise mainly from the fact that, along the Sayan-Baikal arch, the pyroclastics within it are unevenly distributed; they are plentiful in the Tunkin basin, scarce in the South-Baikal, and apparently altogether lacking to the northeast (Barguzin basin, southwestern part of the Vitim plateau).

The Quaternary sedimentation can be definitely evaluated only from the glacial epoch on, when a cold climate "mammoth" fauna established itself over the Trans-Baikal. Pleistocene deposits of the interior of the basins, belonging to the sandy formation, are represented by lithologically monotonous mixed-grain sands reaching over 400 m in thickness, in continental basins. Along the depressions' peripheries, the sands are replaced by gravel, pebble beds and boulder accumulations. In the interiors of continental basins, the sands usually built large bodies with ancient consolidated and new wind erosion forms distributed over them.

The best developed is parallel stratification, with some cross-bedding and waviness; cross-bedding is best developed along the periphery. Locally, the sands carry Upper Paleolithic fauna remains of cold climate mammals: mammoth, woolly rhinoceros, northern deer, goat, snowy ram, horse, a bison. In the Tunkin basin, near Engarga village, frozen sands at a depth of over 150 m, carry thin beds of well-preserved peat which evidently was accumulated under tundra of forest-tundra conditions. Furthermore, a dwarfed fauna of fluvio-lacustrine molluscs and cold climate forms of diatom algae is present in sands of the Barguzin a Tunkin basins. The ecological features of flora and fauna, and the lithology of the formation, reflect a fairly rigorous climate during sedimentation, a preponderance of physical disintegration and denudation.

An analysis of the data suggests a connection between the thick sandy formation the Baikal basins and a protracted glacial epoch which left in the highland foothills a thick mantle of glacial and fluvioglacial deposits. The bulk of Pleistocene sands represents lacustrine-glacial and fluvioglacial deposits in the interior of the basins. They may be regarded as outwash plains formed in narrow intermontane valleys, during a continuous and rapid downwarping. Along the basins' periphery, the sand formation contains, alongside the sands and fluvioglacial pebbles, local deposits of a different origin -- proluvial and alluvial. Sands and sandy soils beyond the glacial areas, are chiefly fluvio-lacustrine [14, 15] and locally attain thicknesses of a few meters, as for instance in the Trans-Baikal.

2. MAIN FEATURES OF SEDIMENT ACCUMULATION

A familiarity with the distribution of the main types of rocks throughout the basins (Fig. 2, 3) clearly suggests two stages in the cycle of Cenozoic sedimentation. Roughly each stage is marked by its own relief as an expression of its tectonics, and by its own climate. Judging by the consistency of the mechanical composition of its sediment with a preponderance of fine-grained and argillaceous varieties, the first stage -- the Miocene-Lower Pliocene coal measures -- took place under conditions of gentle relief and a slow downwarping of the basins. The lack of correspondence between the composition of the coal measures and the present proximity of the mountain ridges suggests small effect of the contemporaneous relief on the Miocene-Lower Pliocene sedimentation. Because there are no coarse clastics along the peripheries of the basins, to outline

m, this might mean tectonic activity of magnitude for this stage. The contempo- eous basins were gentle, poorly defined, filled with marsh-lacustrine and fluvial posits coming from a low and poorly veloped land relief.

The Miocene-Lower Pliocene stage bears dence of a humid and fairly warm climate, ging by its warm climate flora of broad- f and mixed forests, with an admixture of tropical forms (magnolia, myrtle, etc.), recognized in imprints and pollen. A lush getation led to coal formation, with the imum conditions along the basins' peri- eries; it is there that the coal beds occur, dging out toward the interior. In the cen- of the basin the organic matter is scat- ed throughout the sediments, only occa- nally forming separate thin layers. Never- less, the amount of organic carbon re- ins still high, 1.5 to 7.2 percent

This epoch was marked by a high develop- ent of diatom algae, resulting in sizable cal accumulation of silicious deposits -- tomaceous clay and diatomite. What has en said on the mode of extraction, redis- bution, and redeposition of SiO_2 in fresh ter basins [11, 12], leads to a belief at the generation of silica gels in the for- ation of the coal measures was so inten- ve as to make possible its extraction by atoms, on a large scale, thus raising the atoms to the rank of rock makers. The eliminary work in the transportation of rge masses of silica is accomplished, parently, only in the process of chemical eathering of the silicates of crystalline cks in the areas of low arches, and in a mid climate. It may also be assumed at, besides SiO_2, chemical extraction of e carbonate radical took place at the same ne, because the coal measures carry casional beds of marl and chemically pre- pitated carbonates, as much as 1.5 m ick.

The behavior of diagenetic iron is inter- sting. Inasmuch as the part of diagenetic on compounds in the coal-bearing deposits small, it may be surmised that the leogeography of the Miocene and Lower iocene, as a whole, encouraged some cumulation of excess iron oxides in the eas of sedimentation. Those amounts of ivalent iron in the sedimentary basins ere converted almost exclusively into fer- us compounds -- pyrite and vivianite. eduction of Fe^3 to Fe^2, which has led to e preponderance of ferrous iron com- unds in the coal measures, is in accord- ce with both the high organic carbon con- nt in this series and with the peculiarities its mechanical composition -- the pre- nderance of clay and silt varieties. Thus, a relationship is observed here, between the mode of the diagenetic mineral formation, the mechanical composition, and the organic matter of the sediments, as established by N.M. Strakhov [13], in the last years. Judging by the preponderance of fine-grained material and of ferrous iron compounds, the Miocene and Lower Pliocene sedimentation progressed comparatively slowly, just compensating for the downwarping of the basins. Consequently, even this line of evidence points to a low relief during the formation of the coal-bearing series.

The second stage of Cenozoic sedimentation ran under the conditions of progressive cooling initiated earlier, decreasing humidity, and the development of mountain-forest and lowland-steppe landscapes. It embraces all of the Upper[1] Pliocene and the Quaternary. The composition of the "ochre" and the tuffaceous sedimentary formations suggests that the main part in their formation was played by piedmont, fluvial, proluvial, and clastic volcanic deposits and, to a smaller extent, by marsh-lacustrine and lacustrine, with the basins' boundaries defined by a coarse clastic facies. On the other hand, the composition of later Neogene deposits suggests a violent uplift of mountain ranges against the background of an intensified Baikal regional uplift and an intensive subsidence within the basins. The speed of accumulation of the material brought from the ranges was very great. The late Neogene tectonic conditions and the cooling off, precluded any formation of coal. The measurements of organic carbon from the "ochre" formation suggest that the organic accumulation was smothered by a rapid accumulation of clastic, chiefly coarse, material.

Despite the intensity of sedimentation, the deposits could not keep up with an increasing capacity of the basins; consequently, some of them, because of their great vertical movement, became storage basins for large volumes of water.

In the opinion of many geologists, the formation of lakes in the confines of the Baikal and Kosogol basins occurred during this epoch. The amount of storage space is different with different depressions; it is the largest for the Baikal basin -- the largest fresh-water basin in the world. While the character of the early Neogene sedimentation was more or less the same for all

[1] Differentiation of the Baikal Pliocene into Upper and Lower is tentative, because of inadequate paleontologic data. In the future, the age of the "ochre" formation may be better defined within the Pliocene framework.

all basins, the Upper Pliocene marks a change in the sedimentation of the Baikal basin, with its large and deep lake, as compared to dry basins. The unique aspect of this phenomenon unfortunately is not subject to evaluation, because the Upper Pliocene Baikal deposits nearly everywhere lie below the lake surface, outside of the scope of direct observation, as yet. As to the coarse clastic sediments of the "ochre" formation, along the southeast Baikal shore, accumulated in piedmont conditions, they are similar to subaerial alluvial-proluvial deposits of other contemporaneous deposits, both in their origin and composition.

It has been stated that many rocks of the "ochre" formation carry traces of intensive weathering. They occur nearly everywhere -- in the extreme southwest (Tunkin depression) and the extreme northeast (ancient pebble beds of the Vitim River). The "ochre" formation is characterized by an increase in the content of iron oxide hydrates, redistributed during diagenesis as relict grains of terrigenous limonite. The stringers of autogenic hydroxyls commonly contain a small admixture of MnO (0.09 to 0.14 percent) and P_2O_5 (0.15 to 0.38 percent). While the early Neogene process of formation of a weathered crust, as inherited from the Paleogene, was conspicuous in its leaching of mainly mobile components giving raise to silicious and carbonate deposits, the "ochre" formation time witnessed an abrupt halt to this process. From that time on, the chemical weathering becomes secondary, giving the field to physical disintegration which reached its maximum during the Quaternary glaciation. The great amplitude of vertical movements, both plastic and shearing, determined a high degree of relief differentiation of the topography; and the mantle of rock, chemically weathered during early Neogene, together with the excess of ferrous iron compounds, became subject to rapid transportation and burial. The conditions within the basins were unfavorable for diagenetic change of iron to ferrous state. This last conclusion is confirmed, by a low organic carbon content, even for the fine-grained rocks of this formation (0.04 to 0.82 percent); and by the tremendous speed of sediment accumulation, at that time. Under such conditions, according to N.M. Strakhov, a diagenetic transformation and redistribution of the elements did not have the time to develop, because of the quick burial [11]. Incidentally, this is suggested by the relict grains of terrigenous iron hydroxyls. It should be noted that iron hydroxyl concentration in the "ochre" formation is different for different basins; they are most abundant in the Tunkin depression where the natural iron content has been and is high because of a wide distribution of basal flows, with an $FeO + Fe_2O_3$ content of no less than 9 to 10 percent.

To summarize. The suggested differentiation of autogenic components of the terrigenous Tertiary sections for the Baikal type basins reflects a chemical differentiation of matter, in the course of time. Both were determined by a process of weathering of crystalline rocks in the eroded area, and through it -- by the specific tectonic and climatic conditions of each epoch. Such are the general features of continental Cenozoic sedimentation in the Sayan-Baikal basins; they suggest that the Cenozoic history of this province was fairly complex.

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East Siberian Affiliate,
Academy of Sciences, U.S.S.R.
Irkutsk

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THE STRATIGRAPHY AND TECTONIC POSITION OF JASPILITE STRATA OF THE KARSAKPAY SYNCLINORIUM

by

M. S. Markov

ABSTRACT

This study is concerned with the structure and tectonic arrangement of iron quartzite beds in the Precambrian of the southern part of the Ulutau. Two types of jaspilite formations are distinguished, with a discussion of their similarity and differences.

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INTRODUCTION

In the western part of Central Kazakhstan, Precambrian formations are widely distributed, exposed at the surface in the central part of the Karsakpay, Ulutau and Arganatin uplifts.

A study of the Precambrian deposits of the southern part of this territory (the Karsakpay uplift) was commenced by us in 1950 under the direction of N.A. Shtreys. Two colleagues of the Geological Institute of the U.S.S.R. Academy of Sciences, A.L. Knipper and T.G. Pavlova participated in the subsequent work in addition to N.A. Shtreys and myself. The main task of the work was the clarification of the stratigraphy and tectonics of the Precambrian deposits of this broad territory for the purpose of determining the main features of the stratigraphic and tectonic distribution of iron quartzite.

Study of the Precambrian in this region began a long time ago. The pioneers in the study of the ancient strata in the region were I.S. Yagovkin and K.I. Satpayev. To the first of these geologists is attributed the essence of the first stratigraphic system of classification for these strata [27]. K.I. Satpayev was the first to record the large Precambrian fold structures within the boundaries of the region, dividing the Maytyubin and Kuntugan anticlinoria and the Karsakpay synclinorium separating them [25]. The main results of these investigations have not lost their importance even at the present time.

A further study of the Precambrian of the western part of central Kazakhstan was carried out by numerous geologic prospectors within the confines of very limited areas (L.I. Borovikov, A.V. Volin, N.P. Voronov, K.A. Rachkovskaya, A. Ye. Repkina and others). Their investigations threw further light on a number of questions of the stratigraphy and tectonics of metamorphic strata. However, the disclosed principles could frequently be extended only to very small areas. Much of the results of this work is published in the notes by N.G. Kassin [5, 6], who drew up a system of classification of Precambrian deposits of central Kazakhstan.

In recent years the Precambrian of more northerly regions has been studied by I.F. Trusova [17] and L.I. Filatova [18]. Their systems of the stratigraphy of Precambrian metamorphic strata closely follow our own in general outline, but differ in the different stratigraphic positions of some formations and series. These main differences relate to a different interpretation of the age of the lower portions of the Precambrian section.

In addition to questions of stratigraphy and tectonics, some few individual investigations by our predecessors were applied to the special study of iron quartzite and the rocks accompanying them. Such investigations include the works of Yu. Ir. Polovinkina [8, 10, 11], who made a detailed study of the petrography and structure of the iron ore stratum and observed a close relationship between iron quartzite and metamorphosed effusive rocks of basic composition. Of great importance is also the work of M.R. Uzbekov, B.V. Rabinovich, G.A. Kazaryan and K.A. Rachkovskaya on individual deposits of iron ore.

BRIEF STRATIGRAPHIC SYSTEM OF PRECAMBRIAN DEPOSITS OF THE KARSAKPAY SYNCLINORIUM

A group of workers in the Geological Institute under the direction of N.A. Shtreys have worked out a detailed stratigraphic system of classification of Precambrian formations, with a considerable degree of precision in the representation of the tectonic structure and geologic history of the region. It was possible to explain that seams and benches of iron quartzite are present in the middle portion of the Precambrian section, arbitrarily referred by us to the Middle Proterozoic. Not being in a position to examine here the whole complex of Precambrian deposits of the region, we will very briefly describe only the middle portion, that occurs mainly within the boundaries of the Karsakpay synclinorium.

The section of Middle Proterozoic formations begins with rocks of the Turmuza series, overlying lower strata unconformably but with an interruption. Unconformable bedding within the Turmuza series is clearly evident in the region of Kantyube mountain and in a number of other places, where rocks of the Turmuza and the underlying series differ in structure. In addition, pebbles of granite and Lower Proterozoic rocks are contained in basalt conglomerate. The lower part of the Turmuza formation includes various quartzites and graphite microquartzites, with individual lens-shaped seams of conglomerate, and the upper part is made up of mica-amphibole-chlorite and amphibole schist, with quartzite and marble seams. The Turmuza formation is approximately 1,700 m thick.

Higher up, probably unconformably, are rocks of the Tatpen series, represented by porphyroids, and quartz-mica-feldspar schist with fine seams of quartzite schist. This series is roughly 700 to 800 m thick.

The rocks of the Tatpen series are replaced upwards in the section by deposits of the Belkuduk series. Their position in relation to the underlying strata is not quite clear. In a number of places (at elevation 582.2 and at Shaupkelskaya) it has been possible to observe a gradual transition from the porphyroids of the Tatpen series to the overlying formations. On the left bank of the Dyusembay River, however, and in the Akshoky mountain region the rocks of the Belkuduk series were laid down directly on the rocks of the Turmuza series. It is very probable that the position of the Belkuduk series in relation to the underlying rocks varies. In a number of places the rocks of the Belkuduk series are laid down with interruptions in sedimentation, but in other sections a gradual transition can be observed from the rocks of the Tatpen series.

The Belkuduk series is complex in structure. In the northern section of the region (Akshoky and Belkuduk mountains, upper reaches of the Dyusembay River) it consists of massive porphyry, frequently of amygdaloid structure. Individual seams of bright green, actinolite-chlorite and grey to grey-green quartz-mica-feldspar schist are distributed between the thick mantle of metamorphosed lavas. Fine lenses of brown, unstratified marbles are fairly common. The quantity and thickness of the individual schist seams vary sharply, but in the majority of sections there is a predominance of dark-green massive metamorphosed lava together with closely associated actinolite-chlorite schist.

Further south (Say Dzhiyde northern tributaries, Beleuty River) the composition of the Belkuduk series changes. The grey-green quartz-chlorite and quartz-mica-feldspar schist becomes widespread, some variants being very finely stratified. In the schist layers seams of dark green porphyritoid are preserved. At the same time individual benches of iron quartzite occur in the Belkuduk series, associated spatially with the porphyritoids. In the present case and hereafter we will call iron containing quartzite, iron quartzite and not jaspilite because this term is applicable only to the thinly stratified variants, interbedded with red jasper. The Belkuduk series is approximately 1,300 to 1,500 m thick.

Higher up, rocks of the Kumola series occur. In the northern part of the region their contact with the underlying strata is poorly exposed. In the southern part, however, they occur with the basalt conglomerate in the base, which contains rock shingle of the underlying series. The series consists of grey, grey-green, micro-grained, blastopsammitic and blastoporphyritic quartz-mica, quartz-mica-feldspar schist and metamorphosed conglomerate. Among these rocks there is a secondary amount of porphyroid, quartzite schist and marble. The Kumola series is environmentally variable. In the northern part of the region it is made up basically of micrograined quartz-mica schist with individual seams of quartzite schist. To the south there is an increasing content of blastopsammitic and blastoporphyritic, quartz-mica-feldspar schist, porphyroid and conglomerate. The Kumola series is approximately 1,500 m thick.

Higher in the section, the Kumola series gradually gives way to the overlying Keregetas series, consisting of seams of solid, dark green amygdaloid porphyritoid, chlorite-

actinolite, chlorite-actinolite-epidote schist, interlayered with thinly stratified, solid, quartz-mica-plagioclastic schist of grey and grey-green color. In places (in regions of the latitudinal meander of the Dyusembay and Turmuza-Say Rivers) in the upper section of the Keregetas series there are large lenses of bedded marble. On the eastern side of the Karsakpay synclinorium, in the upper part of the series, thin seams of iron quartzites are present, spatially associated with large tabular bodies of greenstone. These rocks are approximately 1,500 m thick.

The deposits of the Kumola and Keregetas series in the eastern side of the Karsakpay synclinorium are almost everywhere converted to porphyroblastic and plagioclastic gneiss, greatly different in external appearance.

Higher up, rocks of the Burmasha series were laid down unconformably after a break in sedimentation. Their unconformable relation to the underlying strata is clearly marked in a number of places (Say Kara-Keregetas and elsewhere), where unconformities occur between the rocks of the Burmasha and Keregetas series. As described below, the structure of the Burmasha series is fairly complicated. They consist of solid, bright-green porphyritoid, frequently of ophitic texture; and green, chlorite-actinolite, actinolite-chlorite-epidote, fine-grained schist, frequently with a very thin, ribbon stratification and sparse seams of porphyroid. In the middle section there are grey, grey-green, quartz-sericite and quartz-chlorite schist, with seams of barren quartzite and iron quartzite and lenses of marble. The overall thickness of the Burmasha series is 1,500 to 2,000 m.

Higher up, rocks of the Karzakpay series were also laid down unconformably. In the initial stages of the study of the Precambrian of this region, a diverse complex of rocks was classified under the name of Karsakpay beds, including rocks of a number of series classifed by us. In L.I. Filatova's system of stratigraphy [18], stratigraphic analogies with the Burmasha series are classified in the more northern parts of the Karsakpay synclinorium, under the term Karsakpay series. In dividing the Karsakpay beds into several series, in 1950-1951, we preserved the term Karsakpay series for the topmost section. These data were subsequently adopted by N.A. Bogdanov [3], in view of which it appears justifiable to classify under the term Karsakpay series that part of the Precambrian section occupying a higher position than the rocks of the Burmasha series.

The Karsakpay series can be clearly divided into three units. In the lower section there can be traced a tabular body of quartzites of diverse external appearance. Their main mass is fine-grained, solid, and has thick, platy variants, nearly always containing hematite. Some quartzites take the form of silicified carbonate rocks, evidence by their direct conversion to marble, and by cavernous surfaces formed during the weathering of these rocks. Much less frequently, rocks of various grain size with fragmental structure occur, frequently associated with breccia type quartzite. Higher up, grey, brownish, quartz-sericite and quartz-sericite-chlorite schist, containing individual quartzite seams are present. In the region of the Keregetas deposit individual lens-type seams of chlorite-actinolite and chlorite schist are contained in this part of the section. The upper part of the formation consists of quartz-sericite and quartz-sericite-chlorite schist, alternating with seams of iron and barren quartzite.

This structure is characteristic of the Karsakpay formation in the central part of the Karsakpay synclinorium, extending between Say-Kensaz and the Keregetas River. In the remaining parts of the region it consists of a 250 to 300 m layer of quartzite, graphite-microquartzite and marble with sparse seams of iron quartzite. The thickness of the rocks of the Karsakpay formation reaches 800 m in its fullest sections.

In the region of the Beleuty River on the rocks of the Burmasha series there is laid down unconformably a layer of violet and green, finely laminated, siliceous and siliceous-sericite schist with marble and sparse seams of iron quartzite in the upper section. These rocks are classified into an independent Beleuty formation. However, we cannot exclude the possibility that they are stratigraphically analogous to the Karsakpay series. The thickness of these rocks is 600 to 700 m. The overlying Precambrian formations, arbitrarily referred by us to the Upper Proterozoic, extend across the rest of the region beyond the boundaries of the Karsakpay synclinorium.

STRUCTURE OF THE IRON ORE SERIES

A brief study has been made above of the stratigraphy of the Middle Proterozoic formations, occurring mainly within the boundaries of the Karsakpay synclinorium. It is apparent from the stratigraphic description that the iron quartzites reappear a number of times in the section and are familiar at least in five formations, namely the Belkuduk, Keregetas, Burmasha, Karsakpay and the Beleuty. At the same time, the first three formations are made up principally of metamorphosed volcanic rocks, but which occur to a very

limited extent or are completely absent in the latter two.

We will study the structure of the Burnasha and Karsakpay formations, because they have been studied in more detail than the remaining iron ore series.

The Burmasha formation, as seen earlier, consists of extremely diverse rocks, formed as the result of metamorphism of various effusive and sedimentary formations. Among the numerous porphyritoids, variants can be classified as the result of metamorphism of aphyric and diabase porphyries and diabase. As shown by Yu. I. Polovinkina [10], the chemical composition of these rocks approximates the composition of spilite. Their spherical cleavage suggests the underwater effusion of these lavas.

Various chlorite-actinolite, actinolite-epidote and other schists characterized by a composition approximating the composition of porphyritoids were formed by metamorphism of tuffaceous rocks. According to the type of fragmental material, Yu. I. Polovinkina [10] has described crystalline-lithoclastic and lithoclastic tuff among them.

Much less frequently there are individual thin seams of metamorphosed acid effusives, among which are albitophyre and quartz albitophyre.

Among the primary sedimentary formations of the Burmasha series there are quartz-sericite and quartz-chlorite schists, probably formed as a result of metamorphism of fine-grained siliceous clay rocks, graphite microquartzite, quartzite-type schist and quartzite -- the products of metamorphism of the essentially siliceous iron quartzite and marble formations.

All these diverse rocks are systematically distributed within the Burmasha series; they replace each other with fair regularity both vertically and spatially.

We will first study the concrete section of the Burmasha series exposed in the valley of the Keregetas River. Here, on the eastern side of the synclinorium, rocks of the Keregetas occur:

1) Chlorite-actinolite and actinolite-chlorite-epidote schist with two thin seams of porphyritoid. The porphyritoid occurs in the middle section of the schist outlier and is roughly 70 m thick; the overall thickness of schist and porphyritoid is approximately 400 m.

Such is the section of the lower portion of the Burmasha series on the eastern side of the synclinorium. Because of the complex tectonics these rocks are exposed again at three outcrops on the latitude of the Keregetas River in the more westerly part of the synclinorium.

In this direction there occurs some modification of the lower portion of the Burmasha series. In successive outcrops of these rocks to the west in the confluence region of the Kara-Keregetas and Kari-Say Rivers, the outlier of rocks, in a similar stratigraphic position, contains a considerable number of porphyritoid seams, with an overall thickness of approximately 200 to 250 m. Farther west, 1 to 1.5 km west of the Kara-Keregetas Mountain, this section of the Burmasha series is made up almost entirely of metamorphosed basic effusives (Fig. 1).

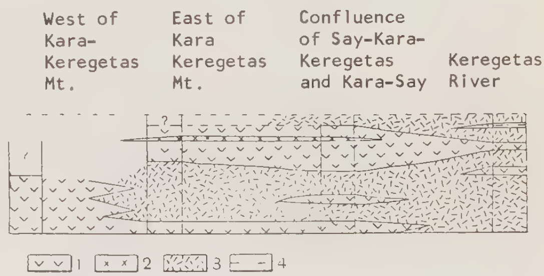

Fig. 1. Diagram of the structure of the lower rider of the Burmasha formation in the region of the Keregetas River and its tributaries -- Say-Kara-Keregetas and Kara-Say.

1-porphiroids; 2-porphiroids; 3-chlorite-actinolite, actinolite-chlorite epidote schist; 4-graphite-microquartzite.

2) Higher up in the section there are quartz-sericite and quartz-chlorite schists, with numerous seams of graphite microquartzite and quartzite schist; in the lower and middle part of the section there are lens-like seams of iron quartzite, each 2 to 3 m thick. The overall thickness of these rocks is approximately 400 to 500 m.

Thus, in the Keregetas River region, the Burmasha series is clearly subdivided into two sections. The lower is made up of chlorite-actinolite and actinolite-epidote schist in the eastern section and porphyritoid in the western. The upper section of the series is made up of divers sedimentary rocks with thin lens-like seams of iron quartzite.

We will examine to what extent the sections of the Burmasha series disclosed in the

Keregetas River section persist laterally. Modifications are clearly evident from the attached map of distribution of sedimentary and volcanic rocks (Fig. 2). Along the north bank of the Kumolo and Kensaz-Say Rivers some variations occur in the structure of the Burmasha series. In the first place, various tuffaceous rocks in the form of chlorite-actinolite and other schists -- widely distributed in the eastern side and lower section of the series, are gradually replaced in the more northerly regions by metamorphosed basic effusives. This phenomenon is clearly observed in the Kumolo River region, where tuffaceous formations occur only in the base of the series as two separate seams, having a total thickness of approximately 100 m, and they disappear entirely in the Kensaz-Say region. On the western side of the synclinorium the lower section of the Burmasha series is more poorly exposed, but in all known outcrops it appears to be a solid stratum of metamorphosed effusives of basic composition.

Some modifications also occur in the higher section of the Burmasha series. The graphite microquartz and quartzite schist seams gradually disappear to the north. As a result of this, the quartz-sericite and quartz-chlorite schist is increasingly predominant. Simultaneously there is an increase in the thickness and extent of the lens-like iron quartzite seams which were observed in the section along the Keregetas River, and the thickness of each of these was 2 to 3 m in the Keregetas River region, it reaches 15 to 20 m in the Kensaz-Say region, with a spread of the individual lens-like seams as much as 2,000 to 3,000 m. North of the Kumolo River there are individual lenses and larger seams of dark-green compact porphyritoid in this section of the Burmasha series.

The structure of the Burmasha series also varies south of the Keregetas River. In the lower section there is an increasing replacement of effusives by tuffaceous rocks. In the region of the latitudinal meander of the Dyusembay River the entire lower section of the Burmasha series is made up of chlorite-actinolite and actinolite-chlorite-epidote schist, with very fine lenses of iron and barren quartzite. South of the latitudinal meander of the Dyusembay River there are layers of lavas, again in the lower section, and their greatest development again occurs in the western side of the synclinorium (Fig. 3).

In the overlying section of the Burmasha series very substantial variations are also observed. Directly south of the Keregetas River it possesses a structure in general approximating that described when examining this section, differing only in the high content of white fine-grained quartzite and in some reduction in iron quartzite seams.

In the upper reaches of the Say-Burmasha, and still more clearly in the middle reaches, there are more substantial modifications. These cause a separation of the sedimentary rocks forming this part of the series into individual layers, stratified between the tuffaceous and effusive formations. The width of these stratified belts ranges from 700 to a few tens of meters, gradually diminishing to the south. They are approximately 700 m to 10 km long (Fig. 2). Most of the belts are characterized by sharp variability along their strike. Within almost each of them a change can be observed from black graphite microquartzite to quartzite and quartz-chlorite schist. Individual sections of the belts contain dolomitic marble. Some of them contain sharply tapering iron quartzite seams. Following them to the south they gradually thin out and vanish, being replaced by tuffaceous and effusive formations.

In studying this process the question repeatedly arose as to whether to regard this type of modification as environmental replacement or as a result of complex isoclinal folding, in which the sedimentary rocks are exposed only in the cores of individual narrow folds whose walls are made up of volcanic formations. Several facts obtained from a detailed study of the regions where these belts are developed apparently confirm the first proposition. Studies of individual sections across the strike of the belts indicates that the spaces between them are made up of different rocks. Consequently these formations cannot be regarded as folds, since it is scarcely possible to assume intense environmental modifications over such short distances. In addition, the elements of stratification of the rocks at the termination of the individual belts do not point to the presence here of centriclinal or periclinal folding. All this points to the fact that in this section of the Burmasha series there are sharply marked changes along the strike. As already observed, these phenomena are more clearly in evidence in the middle reaches of the Sai-Burmasha, where the entire middle section of the Burmasha series, up to that point, made up of only sedimentary formations breaks up, into six belts of approximately equal thickness, consisting of quartz-chlorite schist, barren and iron-bearing quartzite, marble and quartzite schist, ostensibly tapering out into various volcanic rocks. Seven to eight km north of the latitudinal meander of the Dyusembay River the overlying deposits of the Burmasha series appear, dividing the outcrops of the underlying rocks into two sections. In the western outcrops there is a sharp and fairly rapid

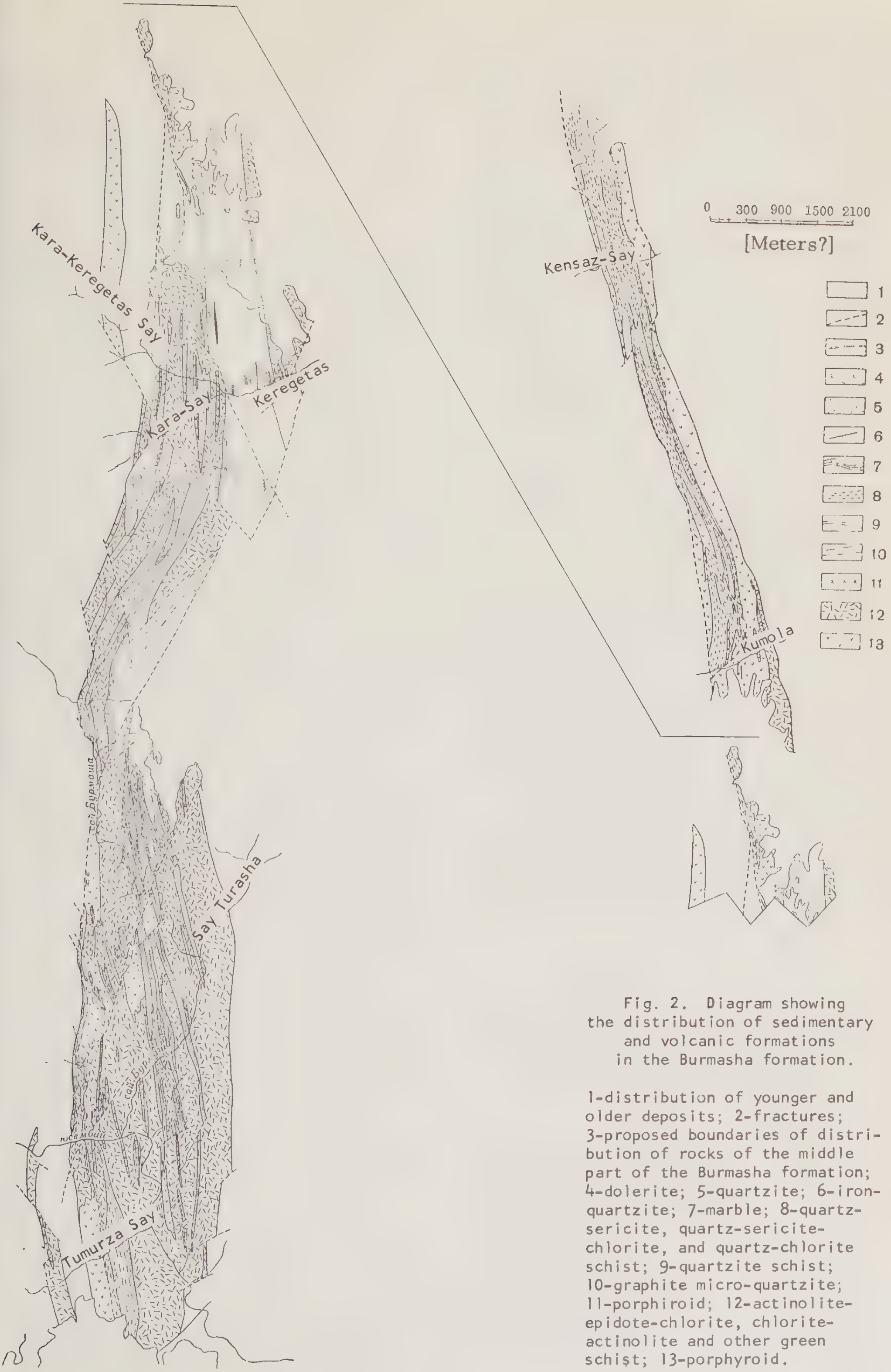

Fig. 2. Diagram showing the distribution of sedimentary and volcanic formations in the Burmasha formation.

1-distribution of younger and older deposits; 2-fractures; 3-proposed boundaries of distribution of rocks of the middle part of the Burmasha formation; 4-dolerite; 5-quartzite; 6-iron-quartzite; 7-marble; 8-quartz-sericite, quartz-sericite-chlorite, and quartz-chlorite schist; 9-quartzite schist; 10-graphite micro-quartzite; 11-porphiroid; 12-actinolite-epidote-chlorite, chlorite-actinolite and other green schist; 13-porphyroid.

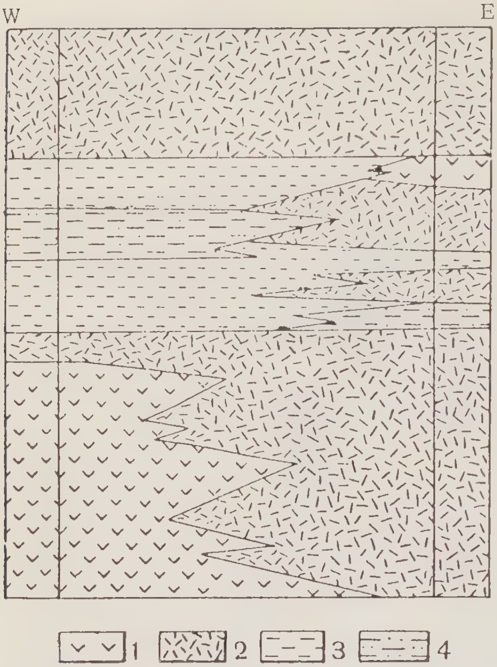

Fig. 3. Diagram of the structure of the Burmasha formation in the latitude of the Say-Tumurza.

1-porphyroid; 2-chlorite-actinolite, actinolite-chlorite-epidote schist; 3-quartz-chlorite schist; 4-graphite-micro-quartzite.

replacement of the sedimentary rocks of the middle sections of the Burmasha series by tuffaceous and effusive formations. In the region of the latitudinal meander of the Dyusembay River only two small seams of black graphite microquartzite remain. Farther south the thickness of the sedimentary rocks again increases sharply, reaching approximately 450 to 500 m at the latitude of the Say-Tumurza (Fig. 3).

Changes in the eastern outcrops of the middle section of the Burmasha series occur somewhat differently. In the middle reaches of the Say-Burmasha four belts of sedimentary formations are exposed, separated by volcanic rocks. To the south a gradual reduction in width occurs, down to a complete tapering out. In the region of the latitudinal meander of the Dyusembay River the number of belts is reduced to three and at the latitude of the Tumurza Say to two, but even these taper out slightly farther south.

South of the Tumurza Say, the rocks of the Burmasha series are covered by Mesozoic and Cenozoic formations and they again crop out only in the valleys of the Shollak-Say and the Beleuty River, where they take the form of quartz-sericite-chlorite schist alternating with black, graphite microquartzite, metamorphosed limestone, with sparse iron-quartzite seams.

The outermost section of the Burmasha series has the simplest structure, cropping out first in the region of the middle reaches of the Burmasha Say. It consists basically of diverse tuffaceous rocks, containing small lens-like bodies of metamorphosed lava. To the south the number of lava sheets increases.

It is apparent from the preceding description that the Burmasha series can be subdivided into three units in a number of places. The lower section is made up of metamorphosed lava and tuff, the lava being more persistent in the section on the western side of the Karsakpay synclinorium and in addition comprising the entire lower section of the Burmasha series on the eastern side to the north of the Kumolo River. The middle section of the Burmasha series is fairly clearly divided into various types of metamorphosed sedimentary formations. These rocks are common in the middle part of the Burmasha series in the northern half of the region studied, being replaced in the region of the middle reaches of the Burmasha Say by metamorphosed tuff and lava. To the south, in the region of the Beleuty River and Shollok-Say, sedimentary formations again occur in the middle part of the series. Again, in the upper section of the Burmasha series metamorphosed tuffs are generally common, with sparse seams of effusives.

This account of the Burmasha series shows that the iron quartzite within its boundaries is characterized by regular occurrence in definite types of sections. They are nearly always located within the middle part of the series, and where tuffaceous rocks are absent. In the region studied there is an increase in number, thickness and extent of iron quartzite seams from the middle reaches of the Burmasha-Say to the Kensaz-Say.

The iron quartzite of the Burmasha series consists of ore and primary siliceous, essentially quartz seams. The ore seams contain hematite, magnetite and martite. Biotite, chlorite, amphibole and albite occur in very small quantities. More frequently the iron quartzite seams are interlayered with quartzite and sericite and quartz-sericite-chlorite schist together with barren quartzite.

Much more rarely it is possible to observe interstratification of the iron quartzite with sheets of lavas (Fig. 4). Lava sheets in contact with iron quartzite, as a rule, are strongly ironized.

A few words here on the variation in thickness of the separate parts of the Burmasha series. It is very difficult and at

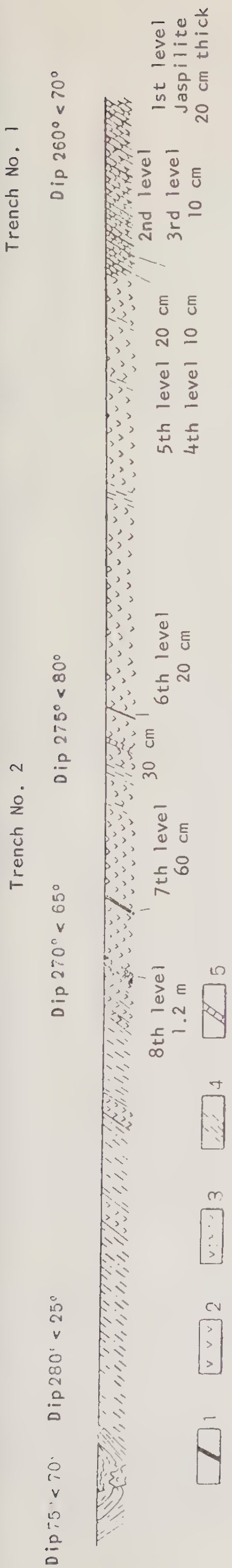

Fig. 4. Geologic section of the iron-ore level of the middle part of the Burmasha formation of the Shagyrla River.

1-iron quartzite; 2-porphyroid; 3-porphyroid transformed into magnetite schist; 4-chlorite and chlorite sericite schist; 5-marble.

times impossible to determine the true thickness in complexly dislocated Precambrian strata, nevertheless it is very probable that from the Kensaz-Say region to the latitudinal section of the Dyusembay River there is some increase in thickness of the middle and lower parts of the Burmasha series, as clearly indicated by the increase in thickness of their outcrops, in areas of more or less similar dip of the seams and absence of fairly large folds. Thus, if estimates of the thickness of the lower section in the Kensaz-Say region yield figures of 250 to 300 m and the middle section 300 to 350 m, then in the Tumurza-Say region the thickness of the lower part of the Burmasha series can be assessed at 600 to 700 m and the middle section 700 to 800 m. The probability of this change in thickness, as we will see later, is in fairly close agreement with the geologic development of the Karsakpay synclinorium.

The overlying Karsakpay series consists of various rock types (quartzite, various schist, marble). The genesis and primary nature of quartzite, like their external appearance, are probably extremely varied. The most common types are fine-grained, compact jasper-type rocks, formed as a result of metamorphism of essentially siliceous deposits having a small quantity of iron oxide. In some sections of the Karsakpay series a substantial part is occupied by cavernous quartzite, the result of silicification and further metamorphism of carbonate rocks. Finally, the third, relatively minor type of quartzites, must be the result of metamorphism of detrital rocks, consisting of quartz-sericite cement, in which there are individual fragments of quartz and quartzite. These rocks are frequently associated with breccia-type quartzite, probably occurring through metamorphism of sedimentary breccia.

The quartz-sericite, quartz-sericite-chlorite and quartz-chlorite schist of the Karsakpay series are undoubtedly the result of metamorphism of siliceous-clay deposits, with small additions of coarser fragmental material, as evidenced by the presence in some of them of quartz porphyroblasts.

The iron quartzites, very much like similar rocks of the Burmasha series, are metamorphosed silica-iron rocks. In addition to iron quartzite, hematite schist consisting in the main of hematite, quartz and sericite, is widely distributed.

In the individual section of the Karsakpay series metamorphosed siliceous and carbonate rocks are widely present in the form of graphite micro-quartzite, quartz schist and marble.

The genesis of chlorite-actinolite and actinolite-chlorite-epidote schist is not quite clear. These rocks may be formed either through metamorphism of tuffaceous rocks, or through scouring of volcanic formations of the underlying Burmasha series and their subsequent metamorphism.

The Karsakpay series is constructed differently in different parts of the regions studied. The most complete section is known in the regions of the Balbraun and Keregetas beds, where they are divided fairly clearly into three sections -- the lower, made up of various types of quartzite, the middle, consisting of quartz-sericite, quartz-sericite-chlorite and quartz-chlorite schist with seams of barren quartzite, and the upper, containing seams of iron-bearing and barren quartzite. In the region of the Keregetas bed, above the outlies of quartzite there are seams of chlorite-actinolite and actinolite-chlorite-epidote schist, missing in the remaining sections of the Karsakpay series.

The number of iron quartzite seams in the Karsakpay series, mainly between the Keregetas and Balbraun beds, is not known. Some geologists believe that in the Karsakpay series there is only one iron quartzite seam, occurring in the outermost section. The presence of seven separate ore belts within the Balbraun bed and eight in the Keregetas is explained by the existence of isoclinal synclines, the central parts of which are made up of iron quartzite. The tapering out of the ore belts along the strike is considered to be the result of an uplift along the hinges of the synclinal folds. Yu. I. Polovinkina [11] was the first to point to the possibility of lens-type bedding and partial wedging out of the iron quartzite.

Some data collected specially by the author for explaining this question allows the assumption of the presence of several iron quartzite seams in the Karsakpay series. In the first place, in the region of the Keregetas bed, it is apparent that thin seams of iron quartzite are located directly above the quartzite rider, above which occur quartz-sericite and quartz-sericite-chlorite schist, with thick seams of iron quartzite. In addition, in a region at an elevation of 547.9 m (Keregetas site) the distribution of individual ore belts justifies the assumption of the presence of several iron quartzite seams of different ages in the outer section of the Karsakpay series. Thus, it is evident from Fig. 5 that in the northern section of the Keregetas site, the eight ore belts fall into two sections, converging towards the south. The two inner belts of iron quartzite close up, forming a synclinal fold, the centriclinal folding is clearly evidenced from measurements of the elements of stratification of the

Fig. 5. Diagram of the structure of the Karsakpay formation in the region of the Balbraun and Keregetas beds.

1-quartzite; 2-quartz-sericite, quartz-sericite-chlorite and quartz-chlorite schist; 3-quartz schist; 4-chlorite-actinolite and actinolite-chlorite-epidote schist; 5-iron quartzite; 6-gabbro diabase; 7-fractures; 8-distribution of younger and older deposits.

n quartzite. As it presents itself to us, points to a difference in age between se belts and others to the west and east these. Tapering out of the iron quartzite ems along the strike is difficult to explain the basis solely of tectonics.

These phenomena are more common in northern section of the Balbraun site, ere a gradual impoverishment of iron rtzite in favor of seams of barren rock e-grained quartzite, quartz-sericite and rtz-sericite-chlorite schist), and gradual ering away of the belts of iron quartzite ur toward the termination of the belts. nple tapering-out is also evidenced by the ments of stratification, the absence here centriclinal folding and the digitate form the terminations (Fig. 5).

It should be noted that we are not exclud- the possibility of some repetition of the tion in the region of the Balbraun and regetas sites by way of complex, isoclinal ding and small longitudinal faults. This is the more probable because in some belts iron quartzite, constriction, together with ering-out at a depth, is observed in drill-. However, for a final solution of the oblem as to which of the ore belts should considered a repetition of a given seam iron quartzite as a result of folding, and ich are independent in stratigraphic posi- n, further observations are necessary.

North of the sites, the Karsakpay series anges somewhat. In the base a rider of artzite and overlying schist are distinguish- le. However, the thickness of the quartzite ler is slightly increased. In the region of sites the thickness of the quartzite nounts to 100 to 120 m. Farther north it equal to 180 to 200 m. In the outer schist ction there is a sharp reduction in the antity of iron quartzite seams. This change explained by two circumstances. In the st place there the outer sections of the arsakpay series which contain a large part the iron quartzite seams are absent; in e second place, the absence of a number iron quartzite seams, as it appears to us, explained by lateral changes to the north.

More substantial changes are observed in e remaining areas of the Karsakpay series rther removed from the region of the sites. the central parts of the Karsakpay syn- inorium, north and south of the belt of tcrops of the Karsakpay series, within hich the Balbraun and Keregetas sites are cated, the synclinorium is made up almost tirely of a layer of various quartzites ith sparse seams of iron quartzite and hist, the thickness of which does not ceed 250 to 300 m.

Thus, north and south of the Balbraun and Keregetas sites, the quantity of quartzite in the Karsakpay series increases and probably they partially replace the schist of the upper parts of the section.

Similar variations in the Karsakpay series also are observed to the west, where its deposits, transgressive layers on more ancient formations, take the form of various quartzites and graphite microquartzite, with an overall thickness of approximately 300 m.

In the eastern part of the region, the stratigraphic analogies of the Karsakpay series are a 200-meter layer of marble and quartzite, with thin seams of iron quartzite.

Hence, the most complete and widely-exposed section of the Karsakpay series occurs within the Balbraun and Keregetas sites, where its thickness reaches 800 m.

The thickness of the Karsakpay series falls away laterally to 250 to 300 m. The impossibility of obtaining a detailed comparison of the sections of the separate, disconnected outcrops of the Karsakpay formation prevents the development of an explanation as to what the 300 meter-stratum of quartzite corresponds to. It may represent a stratigraphic analogy of all the rocks of the Karsakpay series of the Balbraun and Keregetas beds, but with equal justification it may be considered as an analogy of only the lower part of the section. Nevertheless, for any of the variants it is true, without doubt, that there occurs a lateral variation in the thickness of the Karsakpay series; there is a broad development of quartzite and marble in it, together with a reduction in the quantity of schist and iron quartzite.

The iron quartzite of the Karsakpay series is widely developed in the upper section, where, according to our conceptions, it forms separate bodies in the form of a sheet, tapering out along the strike. The maximum length of these bodies within the confines of the Balbraun bed amounts to 5 km with a width of 200 to 300 m. Within the ore belts the iron quartzite with hematite schist, barren quartzite and quartz-sericite schist (Fig. 6) are particularly foliated.

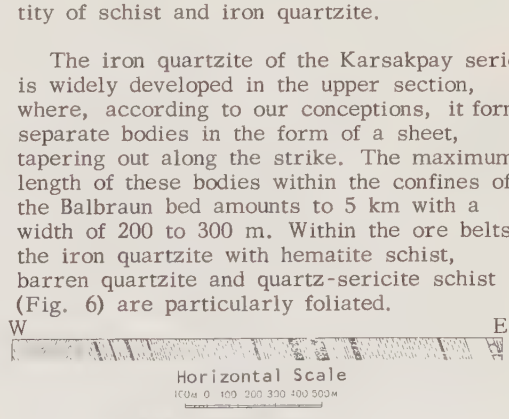

Fig. 6. Sketch of the survey trench through the southern termination of the second ore belt of the Balbraun bed.

1-iron quartzite; 2-hematite schist; 3-quartz-sericite and quartz-sericite-chlorite schist; 4-quartzite.

Comparing the iron quartzite of the Karsakpay and Burmasha series, with their very close similarity, there is also a strong persistence of iron quartzite seams in the Karsakpay series.

TECTONIC ARRANGEMENT OF IRON QUARTZITE

The Karsakpay synclinorium represents a structure extended in the meridional and north-northwest direction, 350 to 320 km long and 30 to 15 km wide. In the cross-section the synclinorium is clearly asymmetric. Its eastern side is flatter and the western side is steeper. Along the course of the synclinorium there are fairly large undulations along the hinge, reflecting the presence of transverse anticlinal folds in its structure.

One of the largest folds is located north of the Kensaz-Say and another lies to the south, in the region of Karsakpay village. The fold structure of the central sections of the synclinorium is fairly simple. There are no supplementary folds appreciably complicating the synclinal structure and only in the central section of the synclinorium, due to the undulations of the hinge, are individual folds clearly marked in the middle section of the Burmasha series. Disregarding the separate transverse, anticlinal folds complicating its structure it is clearly evident that the axis of the synclinorium gradually plunges to the south where it vanishes in the vicinity of the Beleuty River under the Mesozoic and Cenozoic of the Chu-Sarysu basin.

The structure of the synclinorium is complicated as a consequence of the numerous faults trending meridionally, northwest and northeast. The meridional faults are the most interesting, forming natural boundaries of the large Precambrian folds. In particular, this fracture zone follows the contact of the Maytyubin anticlinorium and the Karsakpay synclinorium. However, the most significant for our purposes is another zone of faults trending in the same direction within the synclinorium from the Kensaz-Say to the northern tributary of the Dzhiyde-Say. In the northern part of the region it lies along the western contact of the Burmasha series, gradually leaving the central part of the synclinorium to the west as it trends on southward.

In the region of the northern tributaries of the Dzhiyde-Say it divides into a series of separate parallel faults and farther south probably attenuates gradually. In this zone large dikes of gabbro and gabbro-diabase occur, and approximately parallel to it the fold structures of the Karsakpay synclinorium are retracted to the east. Numerous synclines are associated with it, composed of rocks of the Karsakpay series.[1]

It is very probable that these meridional fracture zones were initiated and developed in the initial stages of development of the Karsakpay synclinorium.

Finally, the tectonic structure of the Karsakpay synclinorium consists of superimposed synclinal structures involving deposits of the Karsakpay series.

In comparing the structure of the iron ore formations with the tectonic features of the Karsakpay synclinorium some interesting conclusions can be drawn. Near the meridional fracture zone, the quantity of effusives increases in the Burmasha formation; these effusives are replaced to the east by tuffs. It is very probable that this zone served as the site of lava emission at the time of deposition of the sediments of the Burmasha formation. This type of regular increase in the quantity of effusive material to the west is clear from the comparative diagram of analogous formations drawn up by L.I. Filatova for the more northerly regions of the Karsakpay synclinorium (Fig. 3), and here the effusive material even replaces the sedimentary rocks of the middle section of the Burmasha formation. Iron quartzite, developed in the middle section of this formation on the other hand, are concentrated more towards the eastern limb of the synclinorium.

The replacement of effusive and tuffaceous rocks in the middle section of the Burmasha formation along the direction of strike by a sedimentary sequence is also very interesting. It occurs from the more depressed sections of the Karsakpay synclinorium in the direction of the uplift of its hinge, and saturation of the middle portion of the Burmasha formation with iron quartzite also increases in this direction. The greatest quantity of quartzite occurs near the large transverse anticlinal fold, the north of the Kensaz-Say. There are not yet sufficient data to verify, with complete reliability, the origin of this structure or its geomorphologic expression at the time of deposition of the rocks of the Burmasha series. In support of this, there is only the lateral change of the Burmasha series and its thickness.

The Karsakpay series is arranged in quite a distinct manner within the Karsakpay synclinorium. Its structures do not follow the

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[1]The concept of joint structures embraces that given by N.P. Kheraskov [19], in describing analogous structures in the South Urals.

structural plan which existed before its deposition. The rocks of the Karsakpay series are not developed in the axial section of the synclinorium but in the central part they are concentrated towards the meridional zone of fracture, along which they form separate fairly narrow synclines. In addition, the rocks of the Karsakpay series consist of numerous superimposed structures in the flanks of the Karsakpay synclinorium, even within the Maytyubin anticlinorium. As we saw earlier, the structure of the series in different parts of the Karsakpay synclinorium is sharply varied. The most complete sections and the ones most saturated with iron quartzite occur in the central part of the synclinorium, in the large synclines. The section diminishes in thickness toward the uplifted parts of the structure and the schist and iron quartzite are replaced by barren quartzite and carbonate rocks.

JASPILITE FORMATIONS OF THE KARSAKPAY SYNCLINORIUM

The study above has been on the structure and tectonic arrangement of the two iron ore formations of the Karsakpay synclinorium; their similarity and differences have been noted. The clarification of individual similarities and differences in the study of the iron quartzite appears extremely necessary to us because only thus can a systematic approach be made to the problem of genesis of these unusual rocks.

The study of iron quartzite (jaspilite) began a long time ago. Numerous works dealing with the genesis of these rocks are widely known in the geologic literature. The overwhelming majority of authors, recognize their primary sedimentary nature; but many offer other explanations for the source of silica and iron. Some investigators consider that the silica and iron of the iron quartzite are the products of chemical erosion, detritus carried off into the sea basin and deposited in the form of siliceous-iron deposits, being converted under metamorphism into iron quartzite [12, 16, 32]. Others hold to the opinion of iron and silicon occurring in the sea basin through volcanic processes [9, 30].

In addition a number of works, some time ago, introduced a third concept involving various sources of iron and silicon, offering a different theory of genesis of iron quartzite. So far as we know, the first mention of this appeared in a paper by Van Hise and Leith [35], in the course of a study of iron quartzite in the Lake Superior region. However, their ideas were presented only in the form of a proposal. Much later, Bruce [28], investigating the iron ore beds of the Canadian Shield, distinguished two types; the first include the iron ore beds of Keewatin age, siliceous type of jaspilite, and the second include iron quartzite beds of Huronian age. For the first type, close association with volcanic rocks of basic composition is characteristic. The second type is associated with sedimentary carbonate and terrigenous formations. The author attempted to classify all the known occurrences of iron quartzite into these two types.

The most complete and precise concept regarding the differences between iron quartzite was set out in 1954 by N.S. Shatskiy, who wrote that "numerous geologic investigations of jaspilite in different matrices have provided reliable facts allowing it to be stated that jaspilite represents one example of convergence of rock types. In other words, jaspilite formations are not uniform; they are similar and analogous, but not homologous, not of one and the same origin; that is to say, among the jaspilites it is necessary to differentiate several types, differing according to origin, and according to group and series, but very similar in general lithologic, petrographic, and textural features" ([23], page 31).

All jaspilite formations are classified by N.S. Shatskiy into two large groups of volcanic-sedimentary origin and of sedimentary origin. In the first group two types of jaspilites are distinguished: (a) of the siliceous schist type and (b) of the distant siliceous formation type.

The Shatskiy paper is again very important because it records the similarity of lithologic-petrographic, and textural features of jaspilite formations differing in origin.[1]

It is probable that in studying such convergent formations it is necessary to study not only the paragenesis of the rocks of each individual formation but also their connection with the adjacent formations, in other words their position in the sedimentary sequence and in tectonic arrangement. A number of supplementary indications may clearly define the differences in otherwise similar formations.

Among the iron quartzite strata of the Karsakpay synclinorium, at least two jaspilite formations can be recognized,

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[1] The concept of "formation" embraces that given by N.S. Shatskiy [23-25].

associated with the volcanic-sedimentary series.[1] In studying the iron quartzite strata in other regions of Precambrian development, it can readily be established that these two types of jaspilite formations are fairly widely distributed and each of them occupies a specific place in the series of volcanic-sedimentary formations.

We classify as a particular type of jaspilite formation, subsequently termed the Keewatin type, the iron quartzite of the Burmasha series with their accompanying complex of siliceous, siliceous-clay and carbonate formations. A characteristic of the Keewatin formation is its close association with greenstone. At the points where the Keewatin formation wedges out there is frequently interstratification of its rocks with volcanic rocks of basic composition. Rocks of the Keewatin formation (iron-bearing and barren quartzite, and schist) also occur in the form of fine lens-shaped bodies within the greenstone formation, occurring in this case as poorly developed fragments of it. The accumulation of rocks of the Keewatin formation occurred simultaneously with thick effusions of lavas and the deposition of tuffaceous rocks, being concentrated towards a single large structural zone within which it took on great development in those sections which were uplifted during the period of sedimentation.

The close association of the Keewatin formation in time and space with volcanic strata of basic composition and their concentration towards uplifted structures relate the described formation with the jasper manganese-bearing formations studied by N.P. Kheraskov [21] in the Paleozoic deposits of eastern Bashkir. Jasper manganese formations of the Bashkir differ from the Keewatin formation only in their smaller thicknesses and smaller area of distribution. It is possible that the Keewatin type of jaspilite formation is the Precambrian homolog of younger jasper formations.

Jaspilite formations of the Keewatin type are widely distributed among the Precambrian formations of different regions. We shall probably attribute to these the iron quartzites of the Belkuduk and Keregetas formations of the regions studied, and iron ore strata of numerous anomalies of the Ulevainian crystalline shield east of the Krivoi-Rog basin are probably of the Keewatin type. An analogous group of formations (greenstone and jaspilite) is known in the southern part of Sind province in India, where, according to the data of J.A. Dunn [29-31], Jones [33] and Krishnan [34], there is a complex series of volcanic rocks of basic composition among the iron-ore series of the Dharwar system, closely associated with siliceous rocks and iron quartzite. However, the most widely developed of the jaspilite formations of the type described has been recognized in deposits of the Keewatin series of the Canadian shield. The Lake Vermillion region is particularly instructive in this respect, being the subject of a detailed study by Van Hise and Leith [35] and later by Bruce [28].

The deposits of the Keewatin series in the Lake Vermillion region can be subclassified into the Ely formation, consisting of metamorphic basic lava and tuff, and the Soudan, consisting of siliceous schist, metamorphic jasper, limestone and iron quartzite. Rocks of the Soudan formation occur in the upper part of the Keewatin series. However, they also replace the volcanic rocks of the Ely formation along the strike, being more widely developed in the zone of transverse anticlinal uplift, clearly delineated in the exposed section through the younger deposits of the Huron series. Hence, there is complete similarity in the structure of the Burmasha formation of the Karsakpay synclinorium and the Keewatin series of the Lake Vermillion region.

In individual cases, even in the presence of thick layers of volcanic rocks, the jaspilite formation of the Keewatin type is very poorly represented. By way of an example of this we can mention the amphibolite series of the Krivoi-Rog where according to A.P. Nikol'skiy [7], only very thin iron-quartzite seams are present. It is not clear at the present time why formations of the Keewatin type are widely developed in some places and very restricted in others. It is possible that appropriate structural-geomorphologic conditions are necessary at the time of deposition for their wide development. It is possible, as thought by Ya. N. Belevtsev [1], that this is connected with chemical differences of the volcanic rocks.

We have grouped with the second type of jaspilite formations, termed the Krivoi-Rog type, the iron quartzite and the various rocks of the Karsakpay series associated with them, that are very similar in texture with the lower and middle divisions of the Krivoi-Rog formation.

The Krivoi-Rog formation differs from the

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[1] At present in the initial stage of the study of formations such elements as superformations, formations and subformations are not accurately defined. It is possible that with the further development of classification the jaspilite formations described will correspond to other elements of this classification.

ewatin first of all by reason of the fact it it is characterized by a more remote sociation with volcanic rocks. Within these rmations only thin and rapidly tapering ams of volcanic rocks occur (chlorite-tinolite and actinolite-chlorite-epidote-hist in the Karsakpay series, and the talc yer in the Krivoi-Rog series). At the same ne, the spatial concentration of iron artzite of the Karsakpay series towards the ne of fracture, which in the preceding age served as the site of effusion of lavas the Burmasha formation, points to a con-ction between this formation and volcanic ocesses. Such a connection is also observed the Krivoi-Rog series, in which synchron-s effusions of basic effusives occur in the stern anomalies [14, 15]. It is very prob-le that the genesis of this formation is nnected with the volcanic stage when marole activity prevailed, either following e stage of lava effusion or synchronous th it, but at a point removed in space.

There are also some differences between e structure of the Krivoi-Rog formation and e Keewatin formation, consisting of the currence of fragmental rocks (breccia type artzite, fragmental quartzite and some hist of the Karsakpay series, with quartz-e of the lower division of the Krivoi-Rog ries) and in the greater persistence of on-quartzite seams.

Laterally and upwards through the section, is formation is replaced by siliceous, liceous-carboniferous and carbonate beds ke the rocks of the upper division of the rivoi-Rog series and quartzite and marble f the Karsakpay series beyond the boundar-s of the Balbraun and Keregetas beds.

The same type of jaspilite formation hould probably also include the iron quartz-e of the Huron series in Ontario and a umber of other regions of the Canadian hield.

According to its position in the series of olcanic-sedimentary formations, this forma-ion is similar to the type of siliceous-schist ormations distinguished by N.S. Shatskiy 23, 24]. The two types of jaspilite forma-ions examined above relating to the volcanic edimentary series, do not by any means xhaust all the variants. Without doubt, urther study of these interesting formations vill bring out, still further, their diversity nd association with various rock sequences, oth volcanic-sedimentary and sedimentary.

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Geological Institute, U. S. S. R.

Academy of Sciences, Moscow.

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NEW DATA ON THE STRATIGRAPHY OF CRETACEOUS COAL MEASURES IN THE LENA BASIN

by

T. P. Kochetkov

I. INTRODUCTION

The section through the coal measures in the Chay-Tumuss region (left bank of Olenek channel on the Lena delta) is of interest because of its position between the Bulun and Olenek areas, whose sections were used by A.I. Gusev as a basis for his subdivision of the coal measures into two components: 1) the lower-Lena, and 2) the upper-Olenek.

The reasons for this differentiation were the findings of fossil wood in the Olenek coal measures. On the basis of these data, A.I. Gusev has recognized here the Upper and Lower Cretaceous coal measures.

By their age and coal-bearing properties, he correlated the Lower Cretaceous deposits with the Lena coal measures (Bulun, Sangary, and other localities), and named them the Lena sequence; the Upper Cretaceous deposits he named the Olenek sequence.

A study of the leafy flora and of spore-pollen spectra of the Lena and Olenek sequences, as carried out in recent years, has shown that both belong to the Lower Cretaceous, except perhaps for the upper Olenek beds (Charchyk formation), whose Cenomanian age as suggested by the presence of angiosperm pollen (up to 16 percent) cannot be ruled out.

Thus, with the exception of the upper beds, the entire section of the Olenek coal measures, as determined by its age, falls into the Lena sequence. This circumstance, as early as 1955, forced me to revise A.I. Gusev's stratigraphic classification, because the term "Lena" has one meaning in the Olenek region, and another in the lower course of the river Lena. To clarify the terminology, it should be remembered that the Lena sequence in the Olenek area has been separated by A.I. Gusev as correlative with the coal measures of the Lena River section because of the following considerations:

1) A Lower Cretaceous age of the lower part of the Olenek coal measures coincides with the age of the Lena River coal measures (Bulun, Sangary, and other localities);

2) Coal measures, exposed in the lower part of the Olenek section, were correlated with the coal measures of the lower Lena.

Because of an erroneous determination of the age of the Olenek sequence, the first premise collapses. For the same reason, the volume of the Lena sequence along the Olenek was artificially restricted. Consequently, the second premise also collapses, because the artificial volume of the Lena sequence along the Olenek was correlated with its true volume in the lower Lena area.

A correlation of paleobotanical layers exposed in the coal measures of the Chay-Tumuss region, with those of the Bulun area makes it possible not only to expose A.I. Gusev's error of correlation of the Olenek and Bulun sections, but also to eliminate the resulting mix-up in the stratigraphy of Cretaceous coal measures in the Lena basin, as a whole.

II. SECTION OF CHAY-TUMUSS COAL MEASURES

The Chay-Tumuss coal-bearing deposits are underlain, as they are elsewhere in the north Lena basin, by sediments carrying a marine, Valanginian fauna.

As a result of geologic surveys by I.G. Nikolayev (1941-1942), K.V. Solov'yev (1949), M.M. Malandin (1949-1951), P.I. Glushinskiy (1950-1951), E.A. Kononova (1951), E.I. Sorokova (1951), and I.I. Vashchenko (1953-1955), it has been established that the Chay-Tumuss coal measures are similar, in their lithology and coal-bearing properties, to those of the lower Olenek. This similarity was confirmed by geologic mapping which revealed the continuity of formation and levels identified along the Olenek, from there

to Chay-Tumuss.

On the basis of these facts, the classification of the Olenek coal measures is extended over the Chay-Tumuss coal measures, where the correlatives of the Olenek section are identified in the following stratigraphic sequence:

a) Lena sequence: beds, first sand; first coal; second sand; second coal; third sand; third coal;

b) Olenek sequence: series Lukumay, Ukin, and Meng-Yuryakh.

The Lena sequence has been studied in exposures; the Olenek, from boreholes.

According to M.M. Malandin, P.I. Glushinskiy, and E.A. Kononova, the Lena sequence is best exposed along the west tributaries of the Bulkur channel, namely the Bulkur and Soguruu-Masty, where sandstone with an abundant but monotonous marine Valanginian fauna are overlain by similar sand deposits, but barren, and belonging to the Lena sequence which is, reading upward, as follows:

1st sand unit: green and greenish-gray sandstone, medium grained, with carbonaceous plant remains and pebbles of tough sandstone and argillite; thickness, 180 m.

1st coal unit: alternating gray, fine-grained, parallel and cross-laminated sandstone and siltstone; among them, three coal seams, up to 0.2 m thick; overall thickness 40 m.

2nd sand unit: light-gray sandstone, grading upward to yellowish and greenish, medium- to coarse-grained, poorly cemented sandstone, with lentils of coal and occasional pebbles of argillaceous rocks.

The sandstones are marked by layers, lenses, and large spheroid concretions of calcareous sandstone, dark gray to brown in color; thickness, 550 to 600 m.

2nd coal unit: dark-gray siltstone with a lenticular coal seam, up to 0.8 m thick; total thickness, 10 m.

3rd sand unit: sandstone, gray to light-gray, less commonly greenish-gray, medium- to coarse-grained, cross-bedded, carrying carbonaceous plant remains, lentils of coal, and pebbles of assorted rocks; thickness, 200 m.

3rd coal unit: an alternation of sandstone, siltstone, and coal beds up to 3 m thick. The sandstone is dark gray to gray, commonly cross-bedded, fine- to medium-grained, with plant remains.

The following forms have been identified from collections of P.I. Glushinskiy and E.A. Kononova, by N.D. Vasilevskaya [1]: a) ferns - Adiantites sp. nov., Asplenium sp nov. ex gr., A. Dicksonianum Heer., Sphenopteris sp. nov., Gleichenia sp. nov. ex gr., G. cycadina (Schenk) Sew., G. sp., Coniopteris Gracilie (Heer), C. arctica (Heer), C. sp. nov., Cladophlebis sp. I, Cl. sp. 2; b) horsetails - Equisetites cf., Lokoyamai Sew.; c) cycadaceae - Nilssonia orientalis Heer., N. nipponensis Yok., N. sp. nov., 2, Anomozamites angulatus Heer., A. acutilobus Heer., A. Schmidtii Heer., Taniopteris (Oleandra) arctica Heer., T. sp. nov. cf., T. emarginata Oishi; d) Ginkgos - Ginkgo interriuscula Heer., G. digitata (Brongn.) Heer., G. minor Hollek., G. sp. nov., Baiera sp. nov., Phoenicopsis angustifolia Heer., Ph. sp. nov., Sphenobaiera angustiloba (Heer) Florin., Sph. graminea (Nath.) Czekanowskia rigida Heer., Cz. setacea Heer., Ginkgo cf. Huttoni (Sternb.). Heer., Phoenicopsis sp.; e) conifera - Podozamites gramineus Heer., P. Eichwaldi Sohimp., P. sp. nov. 1. ex gr., P. Reinii Geyler., P. sp. nov. 2., P. sp. nov. 3., Pityophyllum Lindstromii Nath., P. Nordenskioldii (Heer.) Nath., P. Etaratschinii Heer., P. sp. nov., Pytyostrobus sp. nov.

According to N.D. Vasilevskaya, the age of this flora is Aptian.

V.A. Vakhrameev identified, from a collection of Vashchenko [2]: Cladophlebis sp., Nilssonia gigantea Krysht. et Pryn., N. Schmidtii (Heer.) Sew., Asplenium foersteri Debeg. et. Ettingshausen., Anomozamites angulatus Heer., Ginkgo cf. Huttonii (Sternb.) Heer., Czekanowskia rigida Heer., Pityophyllum Nordenskioldii Heer., Sphenobaiera cf. angustiloba Heer.

According to V.A. Vakhrameyev, "a majority of the identified forms were recognized in these deposits, by N.D. Vasilevskaya, who determined the age of this flora as Aptian, with which everyone can agree, [2].

Among the forms named, the most characteristic are: Ginkgo digitata, Nilssonia orientalis, various Sphenobaiera, Podozomotes gramineus and other narrow leaf podozamites. These forms are designated by N.D. Vasilevskaya as index fossils for the Bulun series of the Bulun section; their thickness is 200 m. The overall thickness of the Lena sequence is 1,230 m.

The deposits of the 3rd coal unit are overlain by the components of the Olenek

sequence, represented here by the Lukumay, Ukin, and Meng-Yuryakh formations.

The Lukumay formation (from bottom to top) is as follows:

1. Sandstone, gray, greenish-gray, locally dark-gray, medium- to fine-grained, cross-bedded, with numerous fragments of petrified wood, and pebbles of clay rock and coal; thickness, 50 to 60 m.

2. Alternation of dark-gray to gray argillite, siltstone, black carbonaceous shale and light-gray, fine-grained sandstone.

Two coal beds are interbedded with these rocks: the lower is 1.55 m thick, the upper 1.3 m thick. Overall thickness, 15 m.

3. Sandstone, dark-, light-, and greenish-gray, medium- to fine-grained, carrying pebbles of dark-gray siltstone and clay siderite. Local accumulations of pebbles form lenticular beds and lentils of conglomerate. The dark-gray sandstone is rare in the middle part of the unit, with the upper part made wholly of light-gray sandstone. Thickness, 100 m.

4. Alternating gray siltstone and black carbonaceous shale; with a coal bed, over 0.9 m thick, on top. Total thickness, 25 m.

5. Sandstone, light-gray, medium- to fine-grained. Thickness, 20 m.

6. Alternating dark-gray argillite, siltstone, and carbonaceous shale, with a coal bed, from 1.6 to 3 m thick, on top. Occasional imprints of plants identified by V.A. Vakhrameyev [2] as Podozamites gramineus Heer., P. sp. Total thickness, 15 m.

7. Arkosic sandstone, light-gray with greenish tint to gray and dark gray, fine- to medium-grained, cross-bedded, with carbonized plant remains and veins of glossy coal.

The sandstones carry fragments and grains of coal, argillaceous rocks, garnet, and ore minerals. There are occasional lenses of siltstone, argillite, and lentils of coal. Thickness, 225 m.

8. Alternating thick and thin gray, fine- to medium-grained, arkosic sandstone and dark-gray siltstone. Occasional argillite and thin (up to 0.7 m) lenticular beds and lentils of coal and carbonaceous shale. Total thickness, 45 m. Overall thickness of the Lukumay formation reaches 500 m.

Going upward, the Lukumay formation gradually changes to the Ukin formation consisting of arenaceous and argillaceous deposits and associated coals and carbonaceous shale. By the consistency of its coal beds, the Ukin formation is subdivided into the following units (reading from bottom to top):

1. Alternating thick and thin dark gray argillite, siltstone, gray fine- to medium-grained sandstone, beds and intercalations of coal, and carbonaceous shale. Five coal beds occur here, from 0.7 to 3 m thick, also remains of a fauna represented by Coniopteris onichioides Vas et K.-M. Podozamites angustifolius Eichw., Pterophyllum sp., Chladophlebis sp., Nilssonia sp., Pityophyllum Nordenskioldii Heer. Total thickness, 145 to 150 m.

2. Alternating dark-gray siltstone, argillite, and gray fine- to medium-grained, cross- and wavy-bedded arkosic sandstone, with lenticular (up to 2.6 m) beds and intercalations of coal and carbonaceous shale. Total thickness, 275 m.

3. Alternating siltstone, gray sandstone, lenses and lentils of coal and carbonaceous shale. A consistent coal bed, 1.3 m thick, at base.

The flora is represented by Coniopteris onychioides Vas et K.-M., Podozamites sp., Baiera cf. angustiloba Heer., Cladophlebis Browniana (Dunker.), Asplenium aff. Dicksonianum Heer., Podozamites lanceolatus.

Total thickness of the Ukin formation is as much as 430 m.

According to V.A. Vakhrameyev, who identified the Ukin flora, "it undoubtedly has a Lower Cretaceous aspect. Most common is Conopteris onychioide, an index form for the upper half of the Yakutia Lower Cretaceous. This form is fairly common in the top of the Lena series (Ogoner-Yuryakh formation). No Upper Cretaceous index forms have been found." [2].

From bottom to top, the Ukin formations change to coalless beds belonging to the Meng-Yuryakh formation. They consist of light-gray, mixed-grain, cross-bedded arkosic sandstone with grains of coal and argillaceous rocks. The base of the formation locally carries lenticular beds of dark-gray siltstone with intercalations of coal; the exposed thickness of this formation reaches 330 m. Overall thickness of the Olenek sequence is over 1,260 m, and the total of the coal measures is no less than 2,500 m.

III. CORRELATION OF CHAY-TUMUSS AND BULUN SECTIONS, BY PALEOBOTANICAL ZONES

The Bulun region coal measures, according

to data of P.I. Glushinskiy, A. Ye. Ermolayev, and I.I. Migay, are divided (from bottom to top) into the following formations: 1) Kigilyakh, 2) Kyusyur, 3) epi-Kyusyur, 4) Bulun, 5) epi-Bulun; 6) Ogoner-Yuryakh, and 7) Obelokan.

All these formations, with the exception of the Obelokan, belong to the Lena sequence, while the Obelokan is correlated with the Lukumay formation of the Olenek, and belongs to the base of the Olenek sequence.

A leafy flora has been found only in three formations: the Kyusyur, Bulun, and Ogoner-Yuryakh.

As identified by N.D. Vasilevskaya [1], the Kyusyur index forms are: Coniopteris burejensis, C. kolymensis, Cladophlebis leanensis, Cl. whitbiensis, Otozamaites acutidentatus, Ginkgo Huttonii; for the Bulun series: Coniopteris onychioides, Ginkgo digitata, appearance of G. adiantoides, assorted Sphenobaiera, Nilssonia orientalis, Podozamites gramineus, and other narrow-leaf podozamites; for the Ogoner-Yuryakh series: Asplenium rigidum, Gleichenia lobata, Nilssonia comtula, numerous Ginkgo adiantoides, several species of Phoenicopsis, broad-leaf podzomites, Pityostrobus Gusevi.

Correlating the floral list of the Chay-Tumuss and Bulun region (Table 1), we see that the leafy Chay-Tumuss flora is correlative with that from the upper part of the Bulun section, beginning with the Bulun formation at the base; the correlative flora begins with the Sphenobaiera zone which appears in the Bulun formation of the Bulun section; and in the 3rd coal unit of the Lena sequence, in the Chay-Tumuss section.

Both in the Bulun formation of the same region, and the 3rd coal unit of the Chay-Tumass Lena sequence, genus Sphenobaiera occurs alongside Podozomites gramineus and other narrow-leaf podzomites. Both in the Ogoner-Yuryakh formation, Bulun region, and the Ukin formation, Chay-Tumuss region, Coniopteris onychioides occurs in abundance and is associated with broadleaf podozamites.

Thus, the leafy flora of the 3rd coal unit of the Chay-Tumuss Lena sequence is correlative with that of the Bulun formation of the same region; and the flora of the Chay-Tumuss Ukin formation is correlative with that of the Bulun Ogoner-Yuryakh formation.

Correlating by these data the lithologic column of the Chay-Tumuss coal measures with that of the Bulun region (see Table 2), we note that the Bulun Kyusyur formation corresponds to the 1st coal unit of the Chay-Tumuss Lena sequence. An analogue of the

Table 1

Correlation of generic composition of the leafy flora of the Chay-Tumuss and Bulun coal measures.

Geologic age	Chay-Tumuss region	Bulun region
C_1^{4+5}	3rd paleobotanical unit (Ukin formation): Coniopteris onychioides (abundant), Asplenium aff. Dicksoniannum, Cladophlebis Browniana, Podzomites lanceolatus, P. angustifolius, P. sp. Baiera cf. angustilobis, Nilssonia sp., Pityophyllum Nordenskioldii.	3rd paleobotanical unit (Ogoner-Yuryakh formation): Coniopteris onychioides (abundant), Asplenium rigidum, Gleichenia lobata, Nilssonia comtula, numerous Ginkgo adiantoides, several species of Phoenicopsis, broad-leaf podzamites, Pityostrobus Gusevi.
Cr_1^{14}	2nd paleobotanical unit (3rd coal unit): Ginkgo digitata, assorted Sphenobaiera, Nissonia orientalis, Podozamites gramineus, and other narrow-leaf podzamites.	2nd paleobotanical unit (Bulun formation): Coniopteris onychiodes (rare), Ginkgo digitata, appearance of Ginkgo adiantoides, assorted Sphenobaiera, Nilssonia orientalis, Podozamites gramineus, and other narrow-leaf podzamites.
Cr_1^{1+2}	1st paleobotanical unit (1st coal unit): no leafy flora found.	1st paleobotanical unit (Kyusyur formation): Coniopteris burejensis, C. kolymensis, Cladophlebis lenaensis, Cl. whitbiensis, Otozamites acutidentalis, Ginkgo Huttonii.

Table 2

Correlation of Cretaceous coal measures of the Chay-Tumuss and Bulin areas.

Geologic age	Chay-Tumuss area, after P.I. Glushinskiy, M.M. Malandin, T.P. Kochetkov, and others	Bulun area, after P.I. Glushkov, G.A. Ermolayev, I.A. Migay, and others
Cr_1^5	Meng-Yuryakh formation: light gray, cross-bedded, mixed-grain sandstone with coal seams at base. No definite organic remains found. Thickness, 430 m.	Missing
Cr_1^{4+5}	Ukin formation: arenaceous and argillaceous deposits with beds of coal and carbonaceous shale. Abundant fern imprints (1st paleobotanical unit). Thickness 30 m.	1) Obelokan formation: light-gray sandstone with coarse cross-bedding. No definite organic remains found. Thickness 150 m. 2) Ogoner-Yuryakh formation: arenaceous and argillaceous deposits with beds of coal and carbonaceous shale. Abundant fern imprints (1st paleobotanical unit). Thickness, 280 to 320 m.
Cr_1^4	Lukumay formation: greenish-gray sandstone with three wedging-out coal units. Identifiable flora imprints only in lower part. Thickness, 500 m.	Epi-Bulun formation: light-gray sandstone with unidentifiable plant remains. Thickness, 500 to 550 m.
Cr_1^4	3rd coal unit: arenaceous and argillaceous deposits with coal beds. Common plant imprints (2nd paleobotanical unit). Thickness 200 m.	Bulun formation: arenaceous and argillaceous deposits with coal beds. Common plant imprints (2nd paleob. hor.). Thickness 40 to 100 m.
Cr_1^{2+3}	3rd sand hor.: light gray, cross-bedded ss. No identifiable plant remains found. Thickness 200 m. 2nd coal unit: arenaceous and argillaceous deposits, with lenticular beds of coal. No identifiable plant remnants found. (This unit is fully replaced locally by sandstone). Thickness 10 m. 2nd sand unit: light gray sandstone. No identifiable plant remains found. Thickness, 600 m.	Epi-Kyus formation: light gray sandstone. No identifiable plant remains found. Thickness 520 to 800 m.
Cr_1^{1+2}	1st coal unit: arenaceous and argillaceous deposits with coal intercalations. No identifiable plant remnants. Thickness 40 m.	Kyusyur formation: arenaceous and argillaceous deposits with beds and partings of coal. Common plant imprints and brackish fauna remains (3rd paleobotanical unit). Thickness 170 m.
Cr_1^1	1st sand unit: light gray sandstone without coal. No organic remains found. Thickness 170 m.	Kiriglyakh formation: light gray sandstone with lentils of coal. No organic remains found. Thickness 180 to 430 m.
Cr_1^1	Deposits with a Valanginian marine fauna.	

2nd coal unit, Lena sequence, Chay-Tumuss region, is absent in the Bulun section (replaced by epi-Kyusyur sandstones).

The 3rd coal unit, Lena sequence, Chay-Tumuss region, as already mentioned, corresponds in its flora to the Bulun formation, Bulun region. Under this correlation, the Chay-Tumuss Lukumay formation corresponds to epi-Bulun formations, while the Ukin corresponds to the Ogoner-Yuryakh and Obelokan formations.

Significantly, the thicknesses of the correlative units are fairly close. For instance, the interval between the 1st and 3rd coal units, Lena sequence, Chay-Tumuss region, reaches 760 m, and the thickness of the synchronous epi-Kyusyur formation in the Bulun region is as much as 800 m; the Chay-Tumuss Lukumay formation is as much as 500 m thick, and its correlative epi-Bulun formation is 550 m thick; the thickness of the Chay-Tumuss Ukin formation coincides with the total for its correlative Ogoner-Yuryakh and Obelokan formations. Only the 3rd coal unit, Lena sequence, Chay-Tumuss region, and the Bulun formation of Bulun region, do not coincide; while the 3rd coal unit is as much as 200 m, its correlative Bulun formation is 100 m thick. This divergence is explained by erosion of the top of the Bulun formation in that area, prior to deposition of the epi-Bulun formation.

The above correlation shows that the 2nd coal unit of the Lena sequence, separated by A.I. Gusev as an Olenek equivalent of the Bulun formation, wedges out before reaching the Bulun. Facies changes of this unit were recognized for the area between the Olenek and Chay-Tumuss, namely between the upper courses of the Erdiylekh and Mastakh Rivers. In other words, a local coal unit, associated with deposits synchronous with the upper part of the epi-Kyusyur formation, was erroneously taken for an Olenek analogue of the Bulun formation. As a result of this error, the 3rd coal unit, Lena sequence, Olenek region, was correlated not with the Bulun, but with the Ogoner-Yuryakh formation of the Bulun region. Consequently, the 3rd sand unit, Lena sequence, Olenek region, was correlated not with the upper part of the epi-Kyusyur formation, but with the epi-Bulun formation, and so on. In short, the presence of an inconsistent coal unit between the 2nd and 3rd sand units of the Lena sequence brought about an error, as a result of which the Olenek section was raised with relation to the Bulun, beginning with the 3rd sand unit of the Lena sequence; consequently, there were no equivalents in the Bulun section of the Lukumay and Ukin formations of the Olenek.

IV. AGE OF THE PETRIFIED WOOD IN THE OLENEK COAL MEASURES

It was previously noted that the division of the lower Olenek coal measures into two sequences (Lena and Olenek) had been done from data of fossil wood found in the 3rd coal unit of the Lena sequence, and in formations of the Olenek sequence.

As identified by A.V. Yarmolenko, petrified wood of the Olenek coal measures is represented by the following species: a) 3rd coal unit of the Lena sequence - Podocarpoxylon woburnense, Stopes;[1] b) Lukumay formation (D.S. Gantman collection) - Taxoxylon sp.;[2] c) Ukin formation (A.I. Gusev collection) - Cypressinoxylon (Glyptostrobus) neosibiricum Schmal.;[3] C. cf. sewerzowii Mercul.;[4] Taxodioxylon olenskii sp. nov. Jarm;[5] T. districhum Mercul., T. sequoianum auct.;[6] Brachyoxylon sp. (nov?);[7] d) Meng-Yuryakh formation (A.I. Gusev collection) - Cypressionoxylon sp., Podocarpoxylon woburnense Stopes.

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[1] A species described from Aptian sandstone of the Isle of Wight, England, and frequently identified in Aptian-Albian and possibly Lower Cenomanian deposits of the European U.S.S.R., Ural region, Soviet Arctic. According to A.V. Yarmolenko, this is an index form for the uppermost Lower Cretaceous and the base of the Upper Cretaceous.

[2] New species of yew wood, not described and recognized from Soviet Asia. Yews are more or less definitely identified from the Far East, from the Gilyak and Orochen stage upward, but appear to be especially characteristic of the floras of the Amur and Bureya Tsagayan, also of the Tsagayan of Novo-Siberian islands.

[3] Species described from the Novo-Siberian brown coals.

[4] Species described from the Saratov stage (Upper Saratov beds) of the Volga region, and identified from the Far East Paleogene (Zaya-Bureya area, K.P. Myasnikov collection) and Arctic Paleogene (Ugol'naya Harbor, collection of M.I. Bushuyev).

[5] New species of yew. Judging by the leaf imprints, very common in the Tsagayan.

[6] Widely developed Tertiary flora; Paleogene in Northern Asia; to the west, also occurs in the Neogene. A composite species, requiring a critical review of all its material.

[7] Genus Brachyoxylon has been identified from the Raritan formation, U.S.A., usually assigned to the base of the Upper Cretaceous. In the U.S.A., this genus occurs from the Triassic to the Magothi formation (Upper Cretaceous). This is its first Eurasian finding; its stratigraphic significance is as yet obscure.

According to A.V. Yarmolenko, five out of the seven identified species (from the Lukumay and Ukin formations) suggest that these deposits are contemporaneous with the brown coal measures of the Novo-Siberian islands, where I.I. Schmalhausen has described a Tertiary Flora; now, A.N. Krishtofovich and other paleobotonists correlate this formation with the Tsagayan stage of the Amur, Bureya, and Laramie (U.S.A.), which is the boundary horizon between the Upper Cretaceous (Danian stage) and the base of the Paleocene.

Paleobotanically, the Tsagayan-Laramie floras have a fully defined Tertiary aspect, but faunal findings put these localities into the Upper Cretaceous. This divergence of the paleontologic and paleobotanical data is not as yet definitely explained. Genus Brachyoxylon suggests an older age for the deposits. The age of the Meng-Yuryakh formation, as determined from the wood (Podocarpoxylon woburnense Stopes) should be Aptian-Albian (or Cenomanian); consequently, this formation should overlie the Ukin and Lukumay and not vice versa. However, if the wood is redeposited, it obviously should have originated from erosion and redeposition of beds of the Lena sequence.

These data show that the age of the Lukumay and Ukin formations lies in a wide range, from Aptian to and including the Paleocene. It follows that, from the evidence of fossil wood, these formations may be assigned, with the same justification, to either the Lower or Upper Cretaceous, and even to the Tertiary. They cannot be assigned to the latter, because the Tertiary of an adjoining region (east slope of the Kharaulakh) is represented by a different formation consisting of slightly metamorphosed rocks with beds of brown coal, carrying a distinctly different macro- and micro-flora. Nor can they be assigned to the Upper Cretaceous, since Podocarpoxylon woburnense (index form for the Aptian and Albian of the Soviet Arctic) occurs not only in the top of the Lena sequence, but in the top of the Olenek.

There are no reasons to assume a secondary deposition of this form in the top of the latter, since sporo-pollen spectra, according to E.N. Kara-Murza, also point to a Lower Cretaceous age for these formations. Thus, the only remaining alternative is that the Tertiary elements of the Olenek flora appeared as early as the close of Lower Cretaceous. Because of that, and on the basis of a leafy flora, it must be concluded that the Upper Cretaceous age of the Olenek sequence, at least up to the Charchyk series, has been assumed erroneously. Consequently, there is no reason for separation of the Olenek sequence in the Lena basin, because it is contemporaneous with the Lena sequence of the Lena basin (Bulun, Sangary, and other localities), which name was assigned by A.I. Gusev to Lower Cretaceous sediments, up to and including the Albian.

In this understanding of the Lena sequence, only the doubtful upper beds of the Olenek section may be assigned to the Olenek sequence. It follows that the name, "Olenek sequence," should be rejected, since its assignment was done on an erroneous age determination, and on an erroneous correlation of the Olenek and Bulun sections, by their coal properties and lithology.

V. STRATIGRAPHY OF THE CRETACEOUS COAL MEASURES OF THE LENA BASIN

At the Interdepartmental Conference for a unified stratigraphic scheme for Siberia (section of Mesozoic and Cenozoic stratigraphy), in Leningrad (1956), several papers dealt with the stratigraphy of the Lena basin coal measures.

Thus, A.I. Gusev [4], dealing with the subject of the subdivision of the Cretaceous coal measures, proposed the following scheme (from bottom to top):

a) Lena series, in northern regions (north of the Dzhardzhan River) represented in its lower part by marine, non-coal-bearing deposits, paleontologically determined as Valanginian and Lower Hauterivian in the Anabara-Khatanga region, also as the base of the Upper Valanginian in the Olenek and Bulun regions; and in its upper parts by coal measures. South of the Dzhardzhan River the entire Lena series is taken over by coal measures.

Among the coal measures, three sand and three coal formations (Kyusyur, Bulun, and Ogoner-Yuryakh) are recognized. Their age is Valangian-Lower Albian.

b) The Olenek series, represented chiefly by arenaceous and argillaceous rocks with associated coal beds. Its age is believed to be Albian or Cenomanian, possibly with some Turonian beds. In the Olenek region, this series is subdivided into four formations whose analogues lie in the Bulun, Zhigan, and Sangary regions.

c) the Vilyui series, represented by continental, poorly-sorted sandstone with boulder gravel layers, and lenses of clay and lignite. It is tentatively assigned to the Upper Turonian-Danian.

In this classification, the Olenek sequence is now designated by A.I. Gusev as a series with a very restricted time limit. This suggests that the separation of the Olenek series has been done not on age data but on a correlation of the Olenek and Bulun sections by their coal properties.

It is clear from the foregoing discussion, that this correlation is based on an erroneous correlation of coal beds of the Olenek Lena sequence, with the Bulun region coal formations; accordingly the separation of the Olenek series as an individual stratigraphic unit will extend the error over the entire Lena basin. To avoid that, the term, "Olenek series," should be excluded from the proposed scheme. In that case, the Cretaceous deposits will be divided into two series: 1) Lower Cretaceous-Lena and 2) Upper Cretaceous-Vilyui.

The first will include both marine (non-coal-bearing) and coal-bearing Lower Cretaceous deposits; the second -- the Upper Cretaceous coal measures and continental deposits.

Under this scheme, the Lena series will include all of the formations of the Olenek region, with the possible exception of the Charchyk formation, whose age is not definitely known.

VI. SUMMARY

A correlation of the paleobotanical units of the Chay-Tumuss and Bulun sections of the Cretaceous coal measures exposes an error made by A.I. Gusev in his correlation of the Olenek and Bulun sections.

As a result of this error and of an erroneous assignment of the upper part of the Olenek coal measures to the Upper Cretaceous, the volume of the Olenek Lena sequence was artificially restricted, which led to the designation of a so-called "Olenek" sequence comprising the analogues (Lukumay, Ukin formations) of the upper Lena sequence in the area of the course of the lower Lena.

These errors are reflected in a general stratigraphic scheme of the Lena coal basin, where the erroneously designated "Olenek" sequence is given a regional significance.

In order to eliminate this error, the author proposes to abandon the term, "Olenek series," and subdivide the Cretaceous Lena basin sediments into two series: Lower Cretaceous-Lena, and Upper Cretaceous-Vilyui.

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Main Administration

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CERTAIN FACTORS AFFECTING THE DEVELOPMENT OF PSEUDOSTRUCTURES IN THE DONETS BASIN COAL

by

L. Ye. Shterenberg

ABSTRACT

Pseudostructures in coals are revealed in microscopic study, under crossed Nicols. They do not belong to the material of the components, and may originate in all components of coal.

One of the factors affecting the pseudostructures is optical anomaly and anisotropy, appearing in certain definite stages of coal metamorphism and related to the development of finely dispersed mineral inclusions, formed during diagenesis. Principal mineral inclusions are melnikovite-marcasite, pyrite, organic compounds of iron, and certain others.

* * * * *

The use of a polarizing microscope in the study of coal structures revealed their optical anisotropy [1, 7, 8]. Polarized reflected light [9] revealed for the first time peculiar structures in anthracite, whose origin we explained by fractionation of gelled plant tissue of the xylene type, under raised pressure. Experiments by L.I. Sarbeyeva [5], carried out on Donets Basin anthracite show that such structures could not have originated as a result of tissue disintegration, because they reproduce the cellular structure of plant fragments, on the xylovitrene stage. Table 1 gives the ideas of some authors [2, 4, 5, 6] on the character of structures observed in gelled components, under crossed Nicols.

As seen on Table 1, a number of investigators recognize a strong correspondence of structures, as revealed in polarized light, with the original cellular structure of plant fragments which gave rise, as a result of gelatinization, to the several coal components.

In disagreeing with these ideas, we make an attempt to present certain factors affecting the formation of "structures" seen in polarized light, which we call, "pseudostructures."[1]

Our own experiments, carried out in 1953-1954, differ from the preceding in their method, higher magnification (X 600 to 1,500) not previously used, and in the selection of material. The selected coals represented various degrees of metamorphism (from long-flame to and including anthracite), from the Lisichansk, Krasnoarmeysk, Kurakhov, Central, Shakhta, and certain other Donets Basin areas.

As a result of our investigations, it has been ascertained that pseudostructures are not always present in the gelled components of coal. Thus, they are lacking in some cases (see Fig. 1, 1a and 1b); in some others (Fig. 1, 2), a structure of plant tissues, unseen in direct light, is revealed in polarized light because of a difference in composition and consequently in optical properties of the components of cell materials. Plant structures revealed in polarized light are not to be confused with pseudostructures (special structures, secondary structures, etc.). The cellular structures, as revealed in polarized light, do not change with rotation of the microscope table.

Pseudostructures are observed not only in gelled compounds of coal, but also in its matrix (Fig. 3, 1b and 3b), macrospores, resin bodies, microspore accumulation (Fig. 3, 2b and 2c), etc. In their appearance, pseudostructures usually mask the cellular structure of plant fragments (Fig. 1, 3b and 3c), instead of enhancing them. In

[1] V. V. Kalinenko 6 used the term "pseudostructures" for similar structures.

Table 1

Authors of structures seen under crossed Nicols	Xylene	Xylovitrain		Vitrain		
L.I. Sarbeev [5], "Secondary Structures."		Reticulate reminiscent of microcline extinction; or wavy, reminiscent of quartz extinction (transverse sections of plant tissues). Grooved structures (longitudinal sections).				
"Pseudostructures," collective work of V.S. Yablokov, L.I. Bogolyubova, V.V. Kalinenko, K.I. Inosova, A.M. Ishchenko [6].	a) Transversal, sparsely banded (system of a few uneven light bands, oriented transverse to the long axis of xylene lenses).[1] b) Reminescent of granular, or altogether lacking.[1]	With half-filled or filled cell cavities	Lumpy	"A" - Structureless	"B" - Structural	"C" - structureless, seldom with an obscure reticulate structure.
		a) Transversely banded (closely situated uneven thin, light bands, oriented generally transverse, or somewhat oblique, to xylovitrain lenses); b) granular.	Sharply defined lumpy structure of xylovitrain.	a) Weak, finely reticulate (two intersecting systems of comparatively weakly expressed light and dark bands) or weak transverse banded; b) granular.	a) Very weak, finely reticulate transverse-banded, or a pseudostructure related to the reticulate vitrain structure and coinciding with it; sometimes reticulate.	Reticulate, at times lacking.

[1] "a" and "b" designate the pseudostructure character with gelled components, for various positions of the microscope stage.

Table 1 (continued)

Authors of structures seen under crossed Nicols	Xylene	Xylovitrain		Vitrain			
				Structureless	Semi-structural	Structural	Cryptostructural
N.M. Krylov, "Special and secondary structures." [3, 4].	Special structure, subordinated to the original reticulate structure.	Secondary: either grooved (longit. section) or reticulate or wavy (transverse section), depending on cut, and associated with the original tissue structure.		Optical orientation parallel to stratification.	Optical orientation ceases to be associated with cell walls and approaches the orientation of a homogeneous gelled matter.	Same as in xylene and xylovitrain. Depending on cut, either grooved (longit. section) or wavy (transv.).	Grooved structure.
L.N. Bogolyubov, "Structures."		Transverse-fibrous.	Lumpy structure is better defined.	Transverse, finely-fibrous, less commonly granular, at times structureless.	Transverse, finely-fibrous.	Obscure, transverse-fibrous.	

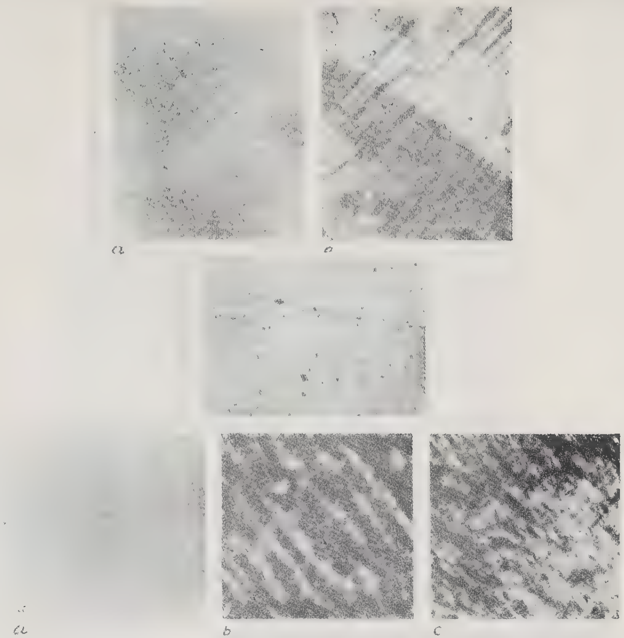

Fig. 1

1a-structural vitrain (bB); Krasnoarmeysk area, shaft 5-5 bis, bed l_7 seam 3; magn. X 600; transmitted light, without analyzer; 1b-same, crossed Nicols; 2-structural vitrain (bB); Nesvetayev area, shaft 43, bed i , seam 2; X 165; reflected light, Nicols not completely crossed; 3a-structural vitrain (bB); Dobropol'ye area, shaft 17/18, bed l_3, seam 3; X 325; transmitted light, without analyzer; 3b-same, crossed Nicols; 3b-same, slide somewhat rotated. Vitrain-AbA; microspores-m; macrospores-ma; accumulation of microspores-mc; basic homogeneous mass-oo; xylovitrain-fusain-kf; cuticle-kt; xylovitrain, lumpy-kbk; basic lumpy (xylovitrain) mass-ok; vitrain B - (bB); vitrain-fusain (bf).

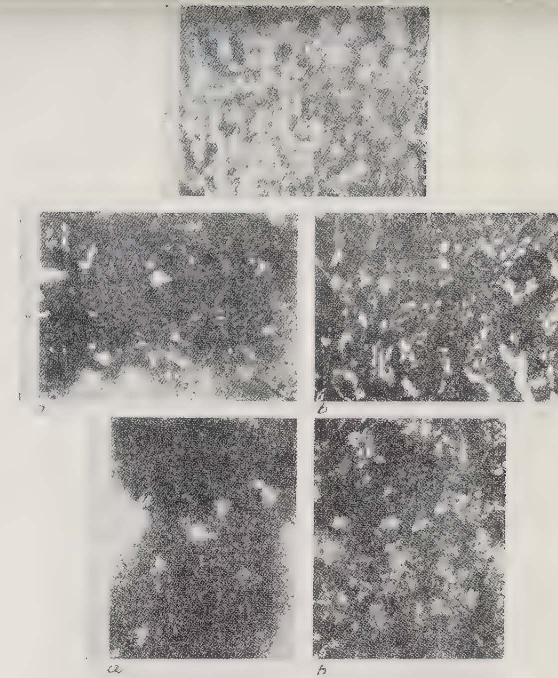

Fig. 2

1-xylovitrain (kB); Shakhta area; Proletarskaya Diktatura shaft, bed K_5^n, seam 2; magnification X 165; reflected light, Nicols not completely crossed; 2a-xylovitrain with half-filled and filled cell cavities; Krasnoarmeysk area; Dimitrov shaft 5/6, bed 1 , seam 4; magn. X 600; transmitted light without analyzer; 2b-the same with Nicols crossed; 3a-vitrain (BA); Central area, shaft 19/20, bed l_3, seam 2; magn. X 600, passing light, without analyzer; 3b-the same with Nicols crossed.

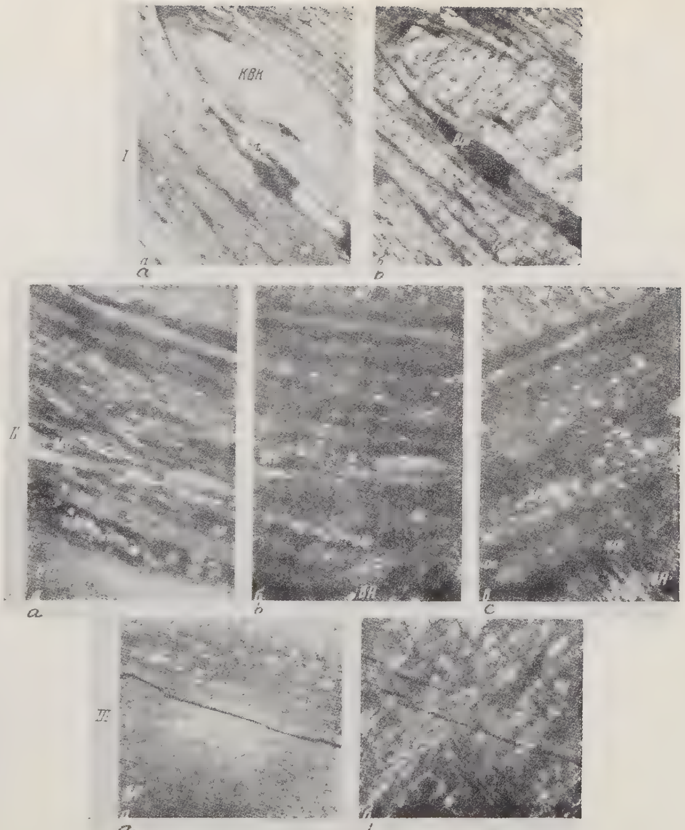

Fig. 3

1a-durain-clarain, xylovitrain-vitrain; Kurakhov area, shaft 42, bed 1 , seam 2; X 165; transmitted light, without analyzer; 1b-same, crossed Nicols; 2a-durain-clarain, cuticle-spore; Kurakhov area, shaft 43, bed l_3, seam 3; X 165; transmitted light, without analyzer; 2b-same, crossed Nicols, slide somewhat rotated from its original position; 2c-same, slide rotated some more; 3a-spore clarain and vitrain (BA); Krasnoarmeisk area, Dimitrov shaft 5/6, bed 1 , seam 5; X 325; transmitted light, without analyzer; 3b-same, crossed Nicols.

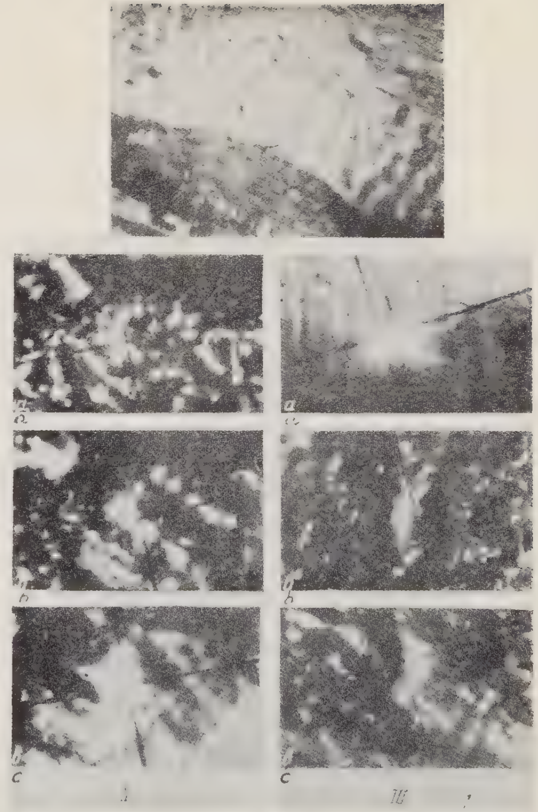

Fig. 4

1-banded pseudostructure in xylovitrain (kB); in weakly fusainized xylovitrain (kBf), primary cell structure is noticeable; Nesvetayev area; Gor'kiy shaft No. 4, bed K_2, seam 2; reflected light; X 165; Nicols not completely crossed; 2a-initiation of a looped structure; Krasnoarmeysk area, Dimitrov shaft 5/6, bed 1, seam 6; transmitted light, crossed Nicols; X 550; 2b-looped structure; same; microscope table rotated 10^{o} from position 2a; 2c-pseudostructure sometimes called "transverse-fibrous"; cell walls (lighter in color) are somewhat bent and deformed; same slide asin Fig. 2a; transmitted light, without analyzer; X 55; 3b-pseudostructure; same; Nicols crossed; 3c-same; table rotated 20^{o}.

rotating the microscope table, the light and dark bands forming the pseudostructures (see Fig. 1, 3b and 3c; Fig. 3, 2b and 2c; Fig. 4, 2a, 2b, and 2c) change their configuration. It is interesting to note that their general character and the direction of the bands (in the case of "banded" pseudostructures) are similar for different coal components (Fig. 3, 1b, 2b, 2c).

A comparison of specimens 3a (without analyzer) and 3b (crossed Nicols) of Fig. 1 convincingly demonstrates a definite relationship between the bands of a "banded" structure and finely dispersed mineral particles, in this instance in the walls and cavities of the plant fragment, with a preserved cellular structure visible under a small magnification.

Diameter of these mineral formations is essentially less than 1 micron. They are scattered not only over the walls and in cavities of the plant fragments' cells, but also throughout the matrix, micro- and macro-spores, cuticle, etc.

Some of them, non-transparent under transmitted light, are rounded, and identified by us as pyrite. The others, both transparent and non-transparent, whose nature we shall discuss below, are of irregular, rounded or elongate, rounded form.

The rounded form, under crossed Nicols and on a rotating microscope stage, produces around itself, because of mechanical strains, a radial extinction not associated with the basic gelled mass and other transparent components of coal.

The irregular form, in our opinion the main cause of the pseudostructure phenomena, affects the extinction of individual coal components in a somewhat different way.

In the vicinity of irregular forms, "cross-shaped figures" appear under crossed Nicols. It is their combined effect, under low magnification, that produces a granular pseudostructure. Fig. 2, 2b, shows "crosses" formed by mineral inclusions in xylovitrain.

As seen in reflected light (Fig. 2 and Fig. 4, 1) minute mineral inclusions in anthracite, located on walls and in cellular cavities, form a semblance to small humps. In polarized light, and under certain orientation of components with relation to the symmetry axis of the microscope, the light is so reflected as to brighten the sides of these humps, and darken their tops and bottoms (or vice versa). Under low magnification, the combined effect of these dark bands gives the impression of a "banded" or some other pseudostructure.

With a small rotation of the microscope stage, the "cross-shaped figures" -- first appearing united to each other -- now form peculiar "looped" structures (Fig. 2, 3b). With further rotation, they grow longer, to form bands giving the impression of a banded pseudostructure.

All of this is graphically illustrated on Fig. 4, 2a, 2b, 2c.

On further rotation of the microscope stage, a system of small "crosses" is first initiated, then "looped" structures, and finally a "banded" pseudostructure, with bands oriented perpendicular to those of the previous pseudostructure.

A special analysis of coal was carried out to determine the nature of finely-dispersed mineral formations.

The most homogeneous and least ashy vitrain was picked out of coal with a needle. This pure vitrain was then finely pulverized. The powder was centrifugally separated in a heavy cadmium fluid, specific gravity of about 2.3. The fluid was removed with a pipette, and the mineral particles washed and dried in a drier (at 90° to $110^{\circ}C$).

The mineral powder thus obtained was studied under the microscope; the presence of extremely small and rare quartz formations, and an abundance of opaque particles was established. A repeated x-ray analysis of the opaque mineral formations revealed that we were dealing with marcasite (see Fig. 5).

However, these mineral inclusions, dark in both the transmitted and the reflected light of the microscope, lack the features which would assign them either to marcasite or to pyrite. This leads to the assumption that the marcasite thus obtained is not crystalline, but a crypto-crystalline variety of iron disulfide, or, more precisely, melnikovite which being a colloidal or metacolloidal iron bisulfide, is revealed by x-rays either as pyrite or as marcasite. A presence of organic iron compounds is most probable, similarly opaque under transmitted light, under the microscope.

The finely-dispersed formations, observed in different coal components, belong to minerals formed diagenetically.

It follows that one of the factors affecting the formation of pseudostructures is the mineral particles which, because of mechanical strains (around them), produce anomalous extinctions in the gelled, cutinized, and weakly fusainized component of coal.

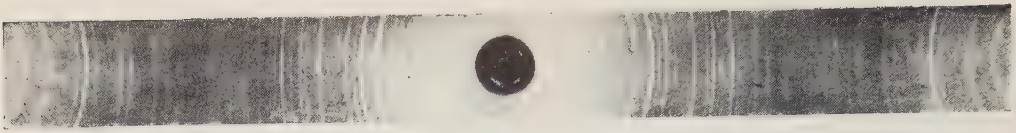

Fig. 5. Debyeogram for marcasite.

Optical anomalies in coal are caused not by mineral particles alone. Thus, an anomalous extinction of gelled material in the vicinity of fusainized fragments, is observed. Under the microscope, the bent, slightly deformed cuticules, macrospores, etc., are also seen to have a radial extinction.

In our opinion, complex pseudostructures are produced in a number of cases by gelled tissues with deformed cell walls. Because of a difference in the optical properties of the components of the cell walls and cavities, they all will have a different extinction. However, a deformation of the cell walls, in bringing about their different orientation, will also result in their different extinction pattern with the rotation of the microscope stage. Finally, mineral admixture may also affect the formation of pseudostructures (Fig. 4, 3a, 3b, 3c).

Our experiments give substance to the statement that pseudostructures (special, secondary structures), as observed in reflected light and under crossed Nicols, do not reflect the original cell structure of the tissues of the coal components, but rather are optical anomalies due to mechanical strains, and appear at definite stages of coal metamorphism.

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Geological Institute
U.S.S.R. Academy of Sciences,
Moscow
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LATEST DATA ON THE LOWER PALEOZOIC OF THE EAST SLOPE OF THE BALTIC SHIELD

by

A. I. Krivtsov

ABSTRACT

New data are cited on the lithology and stratigraphic relationships of the most ancient inian and Cambrian), normal, sedimentary deposits of the east slope of the Baltic Shield.

The formations distinguished here are correlated with well-known deposits of the Baltic ower Paleozoic.

The stratigraphic extent of the Sinian system in the southwest Russian platform is clarified.

* * * * *

INTRODUCTION

There is nothing in the geologic literature, s yet, on the presence and the character of ower Paleozoic normal sediments which are airly well developed along the east slope of ne Baltic Shield (see Fig. 1). Up to recent- y, these most ancient arenaceous and argill- ceous deposits were assigned either to the pper (A.I. Zoricheva, E.A. Kal'berg, 1949) r to the Lower Devonian (L. Ya. Gol'din, 951).

In the summer of 1951, while studying uttings from a deep borehole (BH 2) drilled 1 1950 near the mouth of the Iksa River, a est tributary of the Onega River, I noticed ne so-called "blue clay" typical of the altic Lower Cambrian section. This was mmediately brought to the attention of the eologists of that area. Ever since then, the blue clay" underlying the Devonian along ne middle course of the Onega River has een assigned to the Lower Cambrian. How- ver, this clay, like the underlying sand- ravel deposits, are barren, and their geo- ogic age remains problematical.

In 1954, I studied in detail many bore- ole sections, among them the deep ones long the east slope of the Baltic shield, hich penetrated the full Cambrian section. esides numerous worm tracks, which had een noted also by other geologists (N.G. nd O.A. Kondiayn), the "blue clay" was ound to carry fragments of the chitinous mantle of tubular worms, reminiscent of Sabellidites cambriensis Jan.

On the basis of these findings, and their lithologic similarity with the Baltic rocks, the "blue clay" from the east slope of the Baltic Shield may be definitely assigned to the Lower Cambrian. In the Onega basin, they are underlain by littoral sand and gravel sediments, correlative with the Gdov beds of the Baltic area. Along the south slope of the Windy Belt (Vetrennyy Poyas), the latter lie transgressively upon a crystalline basement, while on the north slope of the Belt they rest upon thick (over 600 m) older, normal sediments represented by argillite, arkosic or quartz-feldspathic sandstone and conglomerate.

Incidentally, it should be noted that the expediency of establishing a new system older than the Cambrian, within the Paleozoic sequence, has been decided upon. Witness the unanimous opinion on that subject by the All-Union conference which took place in January 1955, at the All-Union Geological Institute for Stratigraphic and Geochronological Subdivisions. However, the stratigraphic extent of the new system remains open to discussion. There is also no unanimity as to its name: the Leningrad geologists (including the author) call it Sinian; the others, as seen in Table 1, Eo-Cambrian; finally, N.S. Shatskiy [5, 6] separates all formations between the Iotnian and Cambrian into a Reef group, and assigns them to the

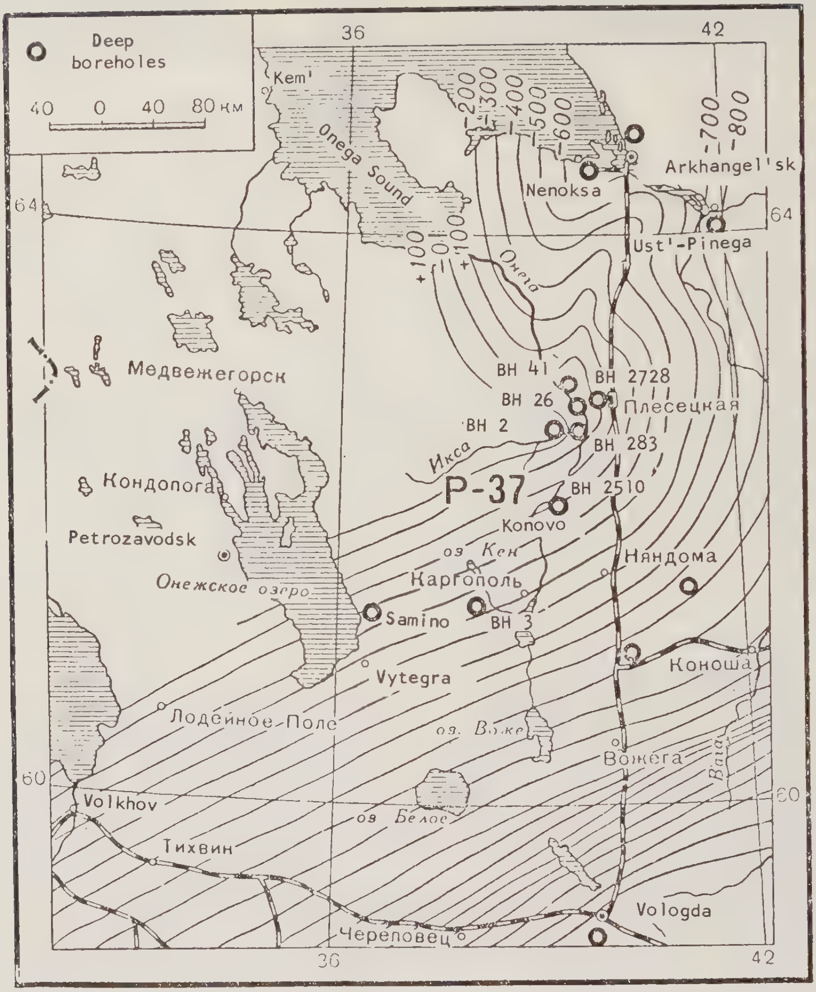

Fig. 1. Index map of the region, showing the relief of the crystalline basement. Scale 1:5,000,000.

(BH = borehole)

Proterozoic; B. S. Sokolov proposed in 1951 [3, 4] to assign the Laminarite clay and Gdov beds of the Baltic section to the Sinian. The 1953 Interdepartmental Conference on Geology and Engineering Geology of Byelorussia and the Baltic area, approved a stratigraphic scheme (see Table 1), apparently with consideration given to the Sokolov idea.

However, this scheme is in contradiction to the data obtained by me as early as 1950, in the processing of samples from the Vilnus stratigraphic borehole. Laminarite clays, penetrated in that well at 361.84-397.40 m (35.56 m), were found to carry numerous remains of the chitinous mantle of Sabellidites cambriensis Jan. worms, very characteristic of the Baltic Lower Cambrian blue clay.

Thus, a Lower Cambrian age for the Laminarite clay and genetically associated underlying Gdov sandstone was recognized unequivocally some time ago [2]. Accordingly, a natural boundary between the Sinian and Cambrian should occur at the base of the Gdov beds, with the stratigraphic extent of the Sinian northwest of the Russian platform restricted to the normal formations and the weathered crust of the crystalline basement between the latter and the Gdov beds.

Table 1

Pre-Ordovician stratigraphy of the Baltic republics and the central parts of the Russian Platform.

Group	System or series	Division or complex	Stage	Horizon	Central regions	Leningrad province	Estonian SSR	Byelorussia SSR
Paleozoic (Pz)	Cambrian	Upper (Cm3)		Pakerort	Hiatus	Dictyonema beds		Hiatus
						Tosna (Obolors) beds		
					Hiatus			
		Middle (Cm2)			Hiatus			
						Izhora formation (Fucoid SS)		Izhora formation (Fucoid SS)
		Lower (Cm_1)			Hiatus			
				Baltic	Hiatus	Eophyton bed	Eophyton bed	Hiatus
					Blue clay bed	Blue clay bed	Blue clay bed	Blue clay bed
					Epi-Laminaria formation	Epi-Laminaria formation	Epi-Laminaria formation	Epi-Laminaria formation
	Eo-cambrian (ECm)	Valdai complex (ECmV)			Laminaria formation	Laminaria formation	Laminaria formation	Laminaria formation
					Gdov formation	Gdov formation	Gdov formation	Gdov formation
					Redkin beds	Hiatus	Hiatus	Hiatus
		Serdobsk complex (ECm^S)			Serdob formation	Hiatus	Hiatus	Orshansk SS (Sub-Gdov formation)

BRIEF DESCRIPTION OF THE LITHOLOGY AND POSITION OF LOWER PALEOZOIC SEDIMENTARY ROCKS

In the northwest of the Russian Platform, including the east slope of the Baltic Shield, Lower Paleozoic deposits are represented by the Sinian and Cambrian.

A. SINIAN FORMATIONS (Sn)

In the subject area, a Sinian age may be assigned to the weathering products of an ancient crystalline basement and to normal arenaceous and argillaceous sediments underlying the Lower Cambrian Gdov beds.

1. ANCIENT WEATHERED CRUST OF CRYSTALLINE BASEMENT ROCKS

The deep Shaben'ga borehole (BH 26, L. Ya. Gol'din, 1950) confirms the fact that the weathered crust of the crystalline basement in the northwestern Russian platform was formed after the deposition and metamorphism of Upper Proterozoic conglomerate. This borehole penetrated the Upper Proterozoic conglomerate which had undergone deep physico-chemical weathering: the main cementing mass was found to be a friable ferrous material, with ferrous iron oxides fully replacing decomposed chloritic material. The pebble components, represented by basic rocks, had undergone strong serpentinization and turned partly to clay.

Thus, the lower age limit for the ancient crystalline weathered crust here is Lower Paleozoic, and the upper limit-Lower Cambrian, as witness the Gdov beds overlying the crust.

Along the middle course of the Onega River, the weathering products of ancient basic crystallines usually occur in depressions in the buried basement relief, less frequently along its slopes, and only as an exception on tops of individual highs. The thickness of this crust is not constant, ranging from several centimeters to 25 m.

Our preliminary data suggest two fairly distinct zones in the weathered crust. The lower zone shows the rocks in an initial stage of weathering; there are a number of incipient fractures filled with carbonates; the rock, while still keeping its original structure, becomes brownish green, greasy to touch, and loses its strength. This zone may be called the initial stage of the loss of molecular cohesion in rock. The iron here is in a ferrous state; there is a deficiency of oxygen. The upper zone is the more important, both as to its thickness and to the qualitative changes in the source material. Qualitatively, it differs sharply from the initial stage of disintegration (or decomposition) of mother rock, by the preponderance of oxidizing processes and an unstable accumulation of basic oxides, Fe_2O_3, Al_2O_3, TiO_2, and SiO_2, with simultaneous leaching of calcium and magnesium carbonate. The rock acquires a clay-like aspect and a red-brown, spotty, intense color, gradually grading in its original structure upward to a clayey mass. This zone witnesses a redistribution of the molecular relationship of the basic components, leading to the formation of kaolin.

As a result of such regrouping throughout the upper zone, kaolin becomes a dominant clay mineral. This is confirmed by the molecular ratios of Al_2O_3: SiO and Al_2O_3 H_2O, as well as by electric logging of the core.

According to B.B. Zvyagin, a computation of the electric log gave a molecular nucleus: $a = 5.14$, $b = 8.90$, $c = 21.5$, and $\beta = 91^{o}$, which is characteristic of typical kaolin with a perfect structure.

Thus, the upper zone is that of kaolin (or kaolinite). Here, no perceptible upward changes are observed, leading to an accumulation of free oxides of aluminum and iron, with simultaneous leaching of silica, which is assumed by the proponents of lateritic formation of bauxites, in this area.

In this connection, of great interest is the balance of molecular quantities of various components in the different parts of the upper section of the crust. It shows but insignificant changes within the zone, resulting either in leaching of alumina and iron, or in leaching of iron and a loss of water, with a mandatory accumulation of silica, which clearly precludes lateritic weathering.

Quite different results are observed in a comparison of the balance of molecular quantities of basic components in two adjoining zones (upper and lower). In this case, there comes a time at a definite stage of weathering of the mother rock, when it decomposes into its components, accompanied by sharp qualitative changes in the entire process. This critical moment, which clearly defines the boundary between the two zones, is marked by a mass leaching of silica, a strong hydration of the weathering products, and a sizable accumulation of alumina and hydrated iron oxides.

As to the subsequent changes in the upper zone of weathered crust, usually taking up a long time, they do not at all lead to a progressive accumulation of free aluminum oxyls, but rather to their leaching.

2. NORMAL SINIAN DEPOSITS

Precambrian normal sediments along the north slope of the Windy Belt, were penetrated by deep boreholes at Pustyn'ka, Arkhangel'sk, Ust'-Pinega, and possibly on the island of Yagra (North Dvina delta). Less certain Sinian deposits are present in the section of the Konosha stratigraphic borehole, and in a deep hole drilled on the southeast shore of Lake Onega, near Samino village (see Fig. 2).

The Pustyn'ka borehole (west bank of the Onega River) penetrated the oldest littoral-

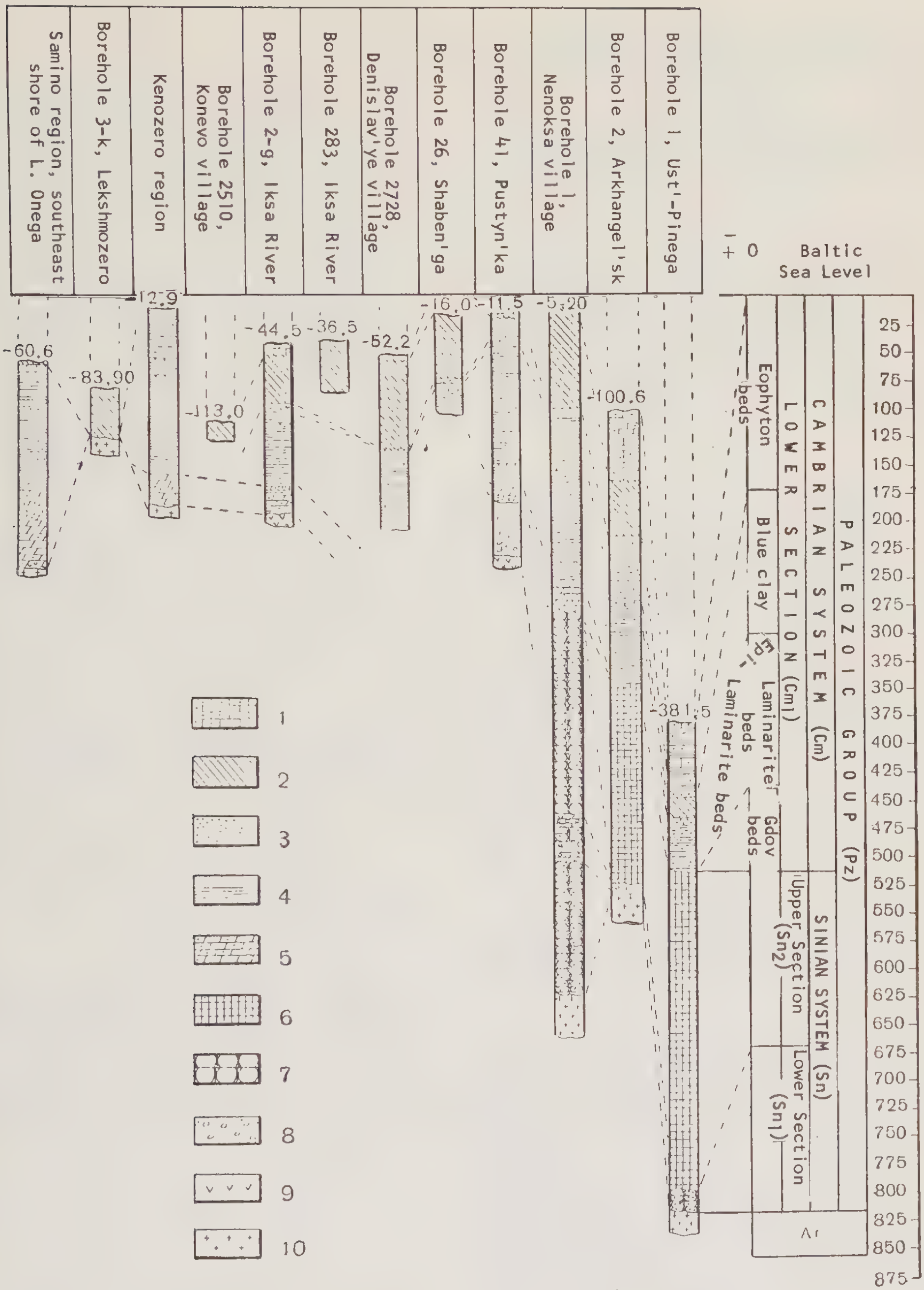

Fig. 2. Correlation of basic Lower Paleozoic sections, penetrated by boreholes along the east slope of the Baltic Shield. Scale 1:2,500.

1-Eophyton beds (Cm c); 2-blue clay (Cm_1b_2); 3-Epi-Laminarite beds $(Cm\ b)^{1}_{1}$; 4-Laminarite beds (Cm_1b_2); 5-Gdov beds (Cm_1a_1); 6-Argillite-like clay (Sn_2); 7-chiefly arkosic sandstone (Sn); 8-chiefly graywacke and conglomerate (Sn_1); 9-basic crystalline basement rocks (Ptz); 10-acid crystalline basement rocks (A).

continental formations at 291.27 to 276.90 m (48.63 m thick). The Sinian rocks here rest directly upon a crystalline basement and are represented by pebble conglomerate whose pebbles are strongly weathered basic greenstone 3-5 cm in diameter. This conglomerate is transgressively overlain by definitely marine Gdov sandstone of Lower Cambrian age.

In the Nenoksa area, Sinian clastic-terrigenous, littoral-continental formations attain a thickness of over 333 m; they rest upon acid crystalline basement rocks. They likewise are transgressively overlain by the marine Gdov sediments. The top of this sequence lies 278.10 m below the present Baltic sea level. I have designated this sequence the Nenoksa formation.

The Nenoksa formation is made up chiefly of mixed-grain, quartz-feldspar sandstone, carrying layers of fine- to medium-grained quartz sandstone. The cement material is of variable composition: usually ferrous clay, less commonly quartz, and still less commonly kaolinite. The rock color is also inconsistent, varying from yellowish-orange to reddish-brown. Roundness of grains and sorting are medium. A rather obscure cross-bedding is observed, with individual layers inclined 10 to 12°. There are local, small, vertical fractures, usually filled with calcite. The deep Nenoksa borehole penetrated the Sinian deposits between 281.7 and 615.5 m. Its middle part (462.0 to 502.9 m) contained gravel and light-purple, coarse- to fine-grained quartz sand.

The rock cement is ferrous kaolinite. The gravel pebbles are chiefly of quartz, rounded and smooth, 3-8 mm in diameter.

Externally, the Nenoksa formation rocks are very much like the Orsha sandstone (Orsha area, B.S.S.R.), assigned to the Eo-Cambrian (Sinian) Serdobsk formation, by the Byelorussian geologists.

As penetrated by the Arkhangel'sk (BH 2) and Ust'-Pinega deep borehole, the Sinian deposits have a different composition. In Arkhangel'sk these formations are penetrated at 353 to 535.75 m. Here they rest directly upon gneissic, rose granite. Underlying the Sinian, there is a thin (1.9 m) conglomerate layer consisting of fragments (5 to 10 cm) of rose granite, cemented by clay. Higher up, there lie thick (180.25 m) littoral-marine terrigenous deposits of closely-alternating, tough meta-clays, greenish gray or reddish brown in color, and very thin (0.1 to 0.5 cm) partings of blue-gray meta-siltstone and fine-grained sandstone. I designate this sequence the Ust'-Pinega formation. In their lithology, the Ust'-Pinega rocks of the subject area are very similar to meta-shales of the Redkin (Sinian) from central areas.

The Ust'-Pinega formation appears to be younger than the Nenoksa formation, and better developed than the latter over the northwestern Russian Platform. Such a stratigraphic relationship is well defined in the Ust'-Pinega borehole (Fig. 2). Near its bottom (803.6 to 826.15 m), this borehole penetrated light-gray quartz sandstone, changing downward (from 822.39 to 826.15 m) to reddish brown micaceous clay with meta-siltstone intercalations. This entire interval rests upon fine-grained basement granite. Apparently, this sandstone and the clays underlying them belong to the Nenoksa formation, because they are transgressively overlain by thick (283.9 m) greenish-gray meta-shale stratigraphically correlative with similar meta-shale of Arkhangel'sk.

The meta-shale (or argillite-like clay) here makes up the Ust'-Pinega Sinian formation and is correlative with the Vekhovsk (complex IV) and Arkhangel'sk (complexes II and III) formations of A.I. Lebedintsev who, after E. Kal'berg, assigns them erroneously to the Upper Devonian.

In the Yagra borehole, the Arkhangel'sk formation is, according to E. Kal'berg, about 66 m thick, with the Verkhovsk formation 47 m thick.

It is possible that conglomerate, gravel and meta-shales, penetrated in the deep Samino borehole (southeast shore of L. Onega) may also be Sinian.

Finally, the Sinian includes greenish-gray, coarse-grained sandstone with pebbles of argillaceous rocks, penetrated by the Konosha stratigraphic test hole. These sandstones are interbedded with fine-grained sandstone and thin green-gray slate. They are found below the Gdov beds, at a depth of 987 to 1,084 m (97 m thick).

B. LOWER CAMBRIAN DEPOSITS (Cm_1)

On the northwestern Russian Platform, Lower Cambrian exposures are found along the shores of the Dvina and Onega bays of the White Sea, also along the lower courses of rivers flowing into these bays.

Unfortunately, ever since Murchison's time and up to very recently, the age of these rocks was thought to be Devonian.

As has been previously recognized, Lower Cambrian deposits are widely distributed beyond their exposures along the east slope

the Baltic Shield where their thickness aches over 270 m.

As seen in Fig. 2 and 3, among the Lower mbrian beds of the subject area there are rly well-defined correlatives of the Baltic ction: the Gdov, Laminarite, epi-Laminar- beds, blue clay, and Eophyton beds (in old nomenclature). The total Cambrian ickness ranges greatly, depending on posi- n in relation to the crystalline basement lief. The greatest Cambrian thicknesses e observed along the north Windy Belt ope, in boreholes Nenoksa (273.2 m), khangel'sk (228.3 m), Pustyn'ka (165.7 m), d Ust'-Pinega (130.0 m).

In the north of the Russian platform, in e area of the above-named boreholes, the ower Cambrian surface plunges sharply to e southeast (from + 5.20 m at Nenoksa to 81.5 at Ust'-Pinega) with a simultaneous crease in thickness (more than double) at e expense of the Laminarite and blue clay. appears that slow but sizable vertical ovements took place over individual locali- es of the subject area, in the Lower Cam- ian, north of the Windy Belt, with the enoksa region at the lowest elevation, and e Ust'-Pinega somewhat higher. On the uth Windy Belt slope, Lower Cambrian posits likewise are subject to considerable anges in thickness. Their minimum thick- ss is established in the Lekshmozero ea (45 m in borehole BH 3). In the Kono- a stratigraphic test well, the overall ower Cambrian thickness reaches 228 m. s upper surface here dips to the southeast, om + 15 m (Kenozero area) to -554.5 m enosha area). As a rule, the Lower Cam- ian thickness is sharply decreased over ghs and increased over lows of the buried ystalline basement relief.

This circumstance suggests, on one hand, e presence of a differentiated Precambrian sement relief; on the other hand, the esence in the subject area, of a Precam- ian littoral-marine zone with an unstable oreline. As to the lithology of the recog- zed formations, it is, generally, as llows.

. GDOV BEDS (Cm_1a_1) (Baltic formation Cm_1pb in A.I. Krivtsov scheme 1, 2])

The lower part of Lower Cambrian sec- on in the subject area is represented by oarse clastic material with subordinate in clay and meta-siltstone. The Gdov beds tand out best in the Nenoksa deep borehole here they lie transgressively upon an roded continental surface of Sinian sand- tone. At the base of the section (280.68 to 281.72 m), the Gdov beds are represented by a thin (1.04 m) bed of coarse pebble con- glomerate of quartz, feldspar, and underlying sandstone.

In the 258.6 to 280.6 m interval, greenish-gray, medium-grained sandstone is present, interbedded with gravel, coarse sand, less common meta-siltstone and sandy clay. Higher up (256.1 to 258.6 m) there is an alternation of coarse-grained sandstone, clay, and meta-siltstone, followed by a thin (0.85 m) layer of coarse-grained sandstone with argillaceous pebbles, thin (0.98 m) dark-brown clay, and finally crowned by quartz-feldspar sandstone with intercalations of the overlying greenish-gray clay (254.2 to 254.7 m).

The Pustyn'ka borehole penetrated the same beds in the 209.8 to 219.2 m interval (9.4 m). They rest upon eroded Sinian con- glomerate. The Gdov beds here are made up of medium-grained quartz sandstone. It should be noted that these beds are missing in the Arkhangel'sk and Ust'-Pinega regions.

On the south slope of the Windy Belt, a full thickness of Gdov beds was penetrated by four deep boreholes. In the Kenosha bore- hole, they were found in the 952 to 987 m interval (35 m). They consist of coarse- to fine-grained quartz sandstone, meta-siltstone and silt with intercalations of blue-green clay.

Within the Kenozero depression, the Gdov beds were drilled through at 272.4 to 300.2 m (27.8 m). They are represented here by mixed-grain quartz sandstone, transgressive over an eroded, acid crystalline basement.

Within the Iksa depression (middle Onega course), the Gdov beds were found only in one borehole, BH 2-G, at 234.4 to 259.25 m (24.85 m). They are represented here by coarse-grained quartz sandstone carrying thin graywacke and conglomerate in their lower part; and thin greenish-gray slate, in the upper. The presence of solitary glau- conite grains suggests their marine origin. Finally, the Gdov beds are penetrated by the Samino borehole, at 214.5 to 240.0 m. This hole was drilled at the village of Samino, on the southeast shore of Lake Onega. Here, the Gdov beds are made of medium-grained quartz sandstone.

Thus, in their lithology, the east Baltic Shield slope Gdov beds are more diversified than those of the Soviet Baltic; however, in their general aspect -- and what is more important, in their littoral-marine origin -- they are fully equivalent to the latter.

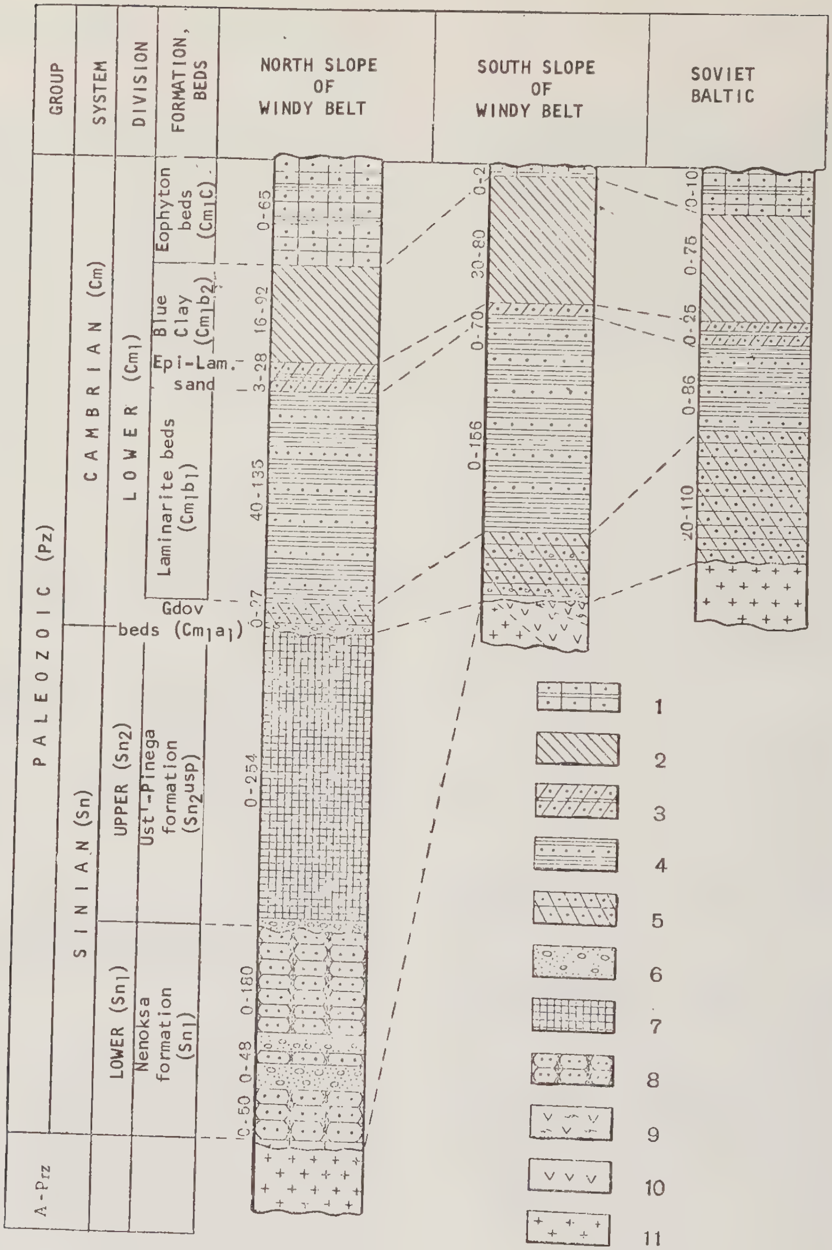

Fig. 3. Correlative stratigraphic scheme for the Lower Paleozoic of the east slope of the Baltic Shield and the Soviet Baltic. Scale, 1:2,500.

1-Eophyton sandstone with layers of clay (Cm_1c); 2-blue clay with intercalations of silt and meta-siltstone (Cm_1b_1); 3-Epi-Laminarite sandstone with intercalations of clay (Cm_1b_1); 4-Laminarite clays with silt and meta-siltstone (Cm_1b_1); 5-Gdov sand and sandstone, locally with graywacke (Cm_1a_1); 6-Conglomerate (Sn_1^n); 7-Meta-shale with thin silt (Sn_1^{usp}); 8-arkosic sandstone interbedded with graywacke and conglomerate (Sn_1^n); 9-weathering product of basic basement rocks (Sn_1); 10-basic crystalline of the basement (Ptz); 11-acid crystallines of the basement (A).

2. LAMINARITE BEDS (Cm_1b_1) (Vilnus beds Cm_1v_1 of Valday formation of A.I. Krivtsov [1, 2])

Wherever the Gdov beds occur along the east slope of the Baltic Shield, they gradually change upward to so-called Laminarite clays. These clays are characterized by their thin stratification, caused by a close alternation of thin pelite and a coarser meta-siltstone. Along the middle Onega course, the Laminarite clays are marked by their high dispersion: the content of fraction < 0.01 mm is commonly 80 to 90 percent. The heavy fraction of these clays is strongly marked by ore minerals, chiefly pyrite, with some hematite and goethite. Its heavy fraction is dominated by micas, with some quartz and feldspar. Mineralogically, these clays are close to the overlying blue clay and consist chiefly of hydromicas with an admixture of kaolinite and a small amount of carbonates. Their average chemical composition may be given as follows: SiO_2 - 50 to 62 percent; TiO_2 - 0.5 to 3 percent; Al_2O_3 - 17 to 20.8 percent; Fe_2O_3 - 5 to 8.2 percent; CaO - 0.3 to 1.5 percent; MgO - 2.5 to 4.5 percent; H_2O - 2.5 to 6 percent; loss on ignition - 4.2 to 9.5 percent.

No exposures of Laminarite clay has been found in the subject area, but it was penetrated by many boreholes. On the north slope of the Windy Belt, their full thickness was penetrated in Pustyn'ka (79.8 to 208.8 m; 130 m); Nenoksa (118.4 to 254.2 m; 135.6 m); Arkhangel'sk (263.7 to 353.5 m; 89.6 m); and Ust'-Pinega (480 to 519.7 m; 39.7 m).

On the south slope of the Windy Belt, the Laminarite clays are traceable in the same depressions that carry the Gdov beds. Their maximum thickness, 171 m (781 to 952 m) was determined here in the Konosha borehole. They are 156 m thick in the Kenozero borehole, 104.7 m in the Onega, and 62.65 m in the Iksa.

3. EPI-LAMINARITE BEDS (Cm_1b_1) (epi-Vilnus beds Cm_1v_1 of Valday formation of A.I. Krivtsov [1, 2])

Above the Laminarite clay, there lie so-called epi-Laminarite beds, as a fairly uniform member of the Lower Cambrian section. In our area, these beds are commonly represented by quartz sandstone interbedded with greenish-gray clay and considerably less common gravel; in the vicinity of the Windy belt, they commonly contain fragments of crystalline rocks.

In the Pustyn'ka borehole BH 41, epi-Laminarite beds are made up of silt; they are penetrated here at 76.8 to 79.8 m; their total thickness is 3.0 m.

In the Nenoksa borehole, the thickness of these beds reaches 17.92 m (from 100.63 to 118.55 m). The epi-Laminarite beds present an alternation of meta-siltstone, clay, and fine-grained sandstone. In the Arkhangel'sk area, their thickness increases even more and reaches its maximum for the subject area, 27.8 m (236.07 to 268.87 m). They are represented chiefly by fine-grained quartz, greenish-gray micaceous sandstone, with intercalations of clay and meta-siltstone.

In the Ust'-Pinega area, the epi-Laminarite beds are penetrated at 475.5 to 480.10 m (4.6 m), as mixed-grain quartz sandstone.

These beds are likewise fairly well-developed along the south slope of the Windy Belt, but their total thickness there does not exceed 16 m (Kenozero area). Their lithology is marked by coarse clastic material commonly with thin layers of graywacke and conglomerate (Iksa depression and area of village Shaben'ga). Going southeast, as shown by the Konosha borehole section, the epi-Laminarite beds descend to a considerable depth (774 to 781 m), with a thickness of but 7 m; they are represented there by friable sandstone and light-brown meta-siltstone.

4. THICKNESS OF "BLUE CLAY" (Cm_1b_1) (Leningrad formation Cm_1ln, of A.I. Krivtsov [1, 2])

Over a large area of the northwestern Russian Platform (including the Soviet Baltic), the so-called "blue clay" is one of the most consistent formations among the Lower Cambrian deposits. Moreover, this formation is a Lower Cambrian marker easily recognizable by its consistent lithology throughout the entire Russian Platform. Along the east slope of the Baltic Shield, the blue clay is traceable almost without interruption, thickening in depressions and gradually wedging out over crystalline basement highs. However, no exposures of these beds have been found in our area. As a rule, they lie here at fairly great depths, with their highest elevation in the central part of the east Windy Belt slope. South and especially southeast of there, the blue clay plunges under younger sediments as low as submarine depths of -60.6 m (village of Samino), -447.7 m (Ust'-Pinega), and even -557.7 m (station Konosha).

Noticeable changes in the thickness of these deposits take place in the same directions. Its greatest values are established in

the Nenoksa borehole (92.13 m), borehole BH 2728 (Denislavskaya depression, 78.5 m) and BH 26 (area of village Shaben'ga, 65.7 m).

Elsewhere, the thickness of blue clay penetrated is considerably less. In all cases, it represents a very close alternation of very fine pelitic and silty material, less commonly with siltstone intercalations, and still less commonly with layers of fine quartz sand, 0.05 to 0.10 m thick. Their color is greenish-gray. Granulometrically, the fine fraction predominates, being 70 to 80 percent, locally 90 to 93 percent for the fraction less than 0.01 mm in diameter. Mineralogically, hydromicas with an admixture of kaolinite, quartz, and carbonate, are substantial components of the blue clay -- as of the Laminarite. It should be noted here that, in their structural and mineralogic aspects, as well as in chemical composition, the blue clay from the east slope of the Baltic Shield and those from the Soviet Baltic are strikingly similar, to the point of being impossible to differentiate. This suggests a similarity in the contemporaneous paleogeographic conditions over a vast area of the northwestern Russian Platform, and a common source of sediment.

A characteristic feature of the blue clay in the Shaben'ga area is the presence of numerous thin layers (0.03 to 0.05 m) of carbonate rocks, locally replaced by strontianite. For organic matter, the blue clay contains isolated remains of tubular worms of genus Sabellidites; worm tracks are not uncommon.

5. EOPHYTON BEDS (Cm_1c) (Vykhma formation Cm_1vh, of A.I. Krivtsov [1, 2])

The Lower Cambrian section of the subject area is crowned by the so-called Eophyton beds, closely related genetically to the underlying blue clay. Commonly, lower Eophyton beds carry numerous layers of blue clay. Their lower boundary is rather indefinite, but their upper boundary is clean-cut.

The Eophyton beds are transgressively overlain by Upper Devonian deposits of a different composition. In the Pustyn'ka borehole, the Eophyton beds are found at 53.59 to 60.52 m (7.07 m). They are represented here by fine-grained sandstone with layers of siltstone and greenish-gray clay, typical in their mineralogic content of the underlying clay.

In the Arkhangel'sk area, the Eophyton sandstone grows thicker, attaining 62.30 m (borehole BH 2, from 125.37 to 87.87 m). They are characterized by numerous siltstones and greenish-gray clay in the lower part of the section. A similar section is found in the Ust'-Pinega borehole, where the Eophyton beds are 55.52 m thick (from 389.6 to 456.12 m). Green-gray shale among sandstone is even more common here than in the Arkhangel'sk borehole BH 2.

Thus, the Lower Cambrian is well developed along the east slope of the Baltic Shield where it is represented by all of the formations known from the Baltic section. However, not all of these formations are well represented, some of them being poorly known.

SUMMARY

As is now recognized, normal Precambrian (Sinian) Lower Paleozoic sediments are well developed over the northwestern Russian Platform.

Genetically, and from their stratigraphic relationship, a binary subdivision of these deposits, into what appears to be the correlatives of the lower and upper divisions of the Sinian system, appears to be most natural. The Lower Sinian period was characterized here chiefly by littoral-continental conditions of sedimentation (represented by the ancient weathered crust of crystalline basement rocks and a thick sandy section of the Nenoksa formation), while the Upper Sinian epoch is represented chiefly by littoral marine argillites of the Ust'-Pinega formation.

A littoral-marine sedimentary environment, with a very unstable shoreline, persisted here throughout the Lower Cambrian. But as early as the close of this epoch, the sea retreated from the subject area, and a vast stretch of the northwestern European U.S.S.R. stood high until the onset of a Lower Ordovician transgression.

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All-Union Geological Institute

(VSEGEI)

Ministry of Geology

and Mineral Conservation, Leningrad

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AGE OF THE ULTRABASIC INTRUSIONS OF THE GORNYY ALTAI

by

V. A. Kuznetsov

ABSTRACT

This paper gives the results of investigation carried out for the purpose of verifying the finding of relatively young Hercinian ultrabasic intrusions in the Gornyy Altai, and exposes some erroneous conceptions. The Gornyy Altai ultrabasic intrusions are typical products of early stages of the development of the Altai Caledonian structures, and are Cambrian in age.

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THE PROBLEM

In recognizing ultrabasic intrusions in certain areas of the Gornyy Altai, and noting their consistent association with exposures of the oldest rocks of the Lower Paleozoic, all investigators unanimously assigned these intrusions to the Caledonian. After having studied the position of these intrusions, and compared them with the better-developed and better-known ultrabasic intrusions of adjacent West Sayan and Tuva, many investigators including myself came to accept a Cambrian, or Salair age, at least for most of the Gornyy Altai ultrabasic intrusions [2, 9, 12, 15, 21, 22]. The idea of an ancient Caledonia, or Salair, age of these intrusions has gained general recognition. Specifically, it was reflected in the author's map of West Siberian ultrabasic belts [13], with two major Cambrian ultrabasic belts shown for the Central and Southeast Altai.

However, these ideas of an ancient age for the Gornyy Altai ultrabasic intrusions have undergone a revision in recent years. There appeared communications on the presence in certain regions of this province, of ultrabasics emplaced in the Devonian and thus being of a post-Devonian, i.e., Hercinian age [6, 7, 19]. Some of the authors of these papers do not even go to the trouble of making a more detailed study of the possibility of two non-contemporaneous ultrabasic intrusions in Gornyy Altai, i.e., both Cambrian and Hercinian, but dogmatically state that "former views of a Cambrian age for the Gornyy Altai ultrabasics are fully refuted by the latest data," and that "now one can speak with certainty of their early Hercinian age" [7]. In this connection, certain geologic reports, and maps of Gornyy Altai now in preparation, contain notations on the alleged Hercinian ultrabasic intrusions, with proper theoretical and practical conclusions.

As a matter of fact, the situation is quite different, and the problem of the presence in Gornyy Altai of Hercinian and generally post-Cambrian ultrabasics cannot be solved in this way. As will be shown below, the recent communication of findings of the alleged post-Devonian ultrabasics are without solid factual substantiation and in no way refute the firmly substantiated conclusion of many previous investigators, of a Lower Paleozoic age for the Gornyy Altai ultrabasics.

The age of the ultrabasic intrusions is a matter of principle. As is well known, ultrabasic intrusions, being associated with volcanic spilite-keratophyre formations in geosynclinal downwarps, appear usually in early stages of the development of mobile zones. It is also known that the ultrabasic intrusions within a given structural zone or a given ultrabasic belt, occur in a single stage and at one time only, not recurring during its subsequent development [9, 11, 17, 23]. Finally, it is known that Gornyy Altai is an essentially Caledonian folded structure, the geosynclinal stage of which occurred at the close of the Proterozoic and in the early Paleozoic [16], and that only its isolated structural facies zones did carry into the Hercinian the tectonics of residual geosyn-

clinal downwarping [14]. It follows that early Caledonian and particularly Cambrian ultrabasic intrusions are quite proper for the Gornyy Altai Caledonian structures whose early development stages took place in the beginning of the Paleozoic; conversely, Hercinian ultrabasic intrusions are hardly probable. A finding of Hercinian ultrabasic intrusions in the Caledonian Structures of the Altai would be of great interest. If true, it would necessitate a revision of our ideas of a regular manifestation of ultrabasic intrusions and ophiolites in general, in definite initial and early stages of development of mobile zones. It would necessitate a revision of the conception of a single-phase ultrabasic intrusion within a discrete ultrabasic belt.

On the other hand, there was a question of the possibility in Gornyy Altai, of Hercinian ultrabasic intrusions of some other type, different from that of the orogenic or folded zones.

Finally, besides its purely theoretical aspect, the problem of younger, Hercinian, ultrabasics of Gornyy Altai is of a practical import. Indeed, an alleged Hercinian ultrabasic Gornyy Altai intrusion, being post-orogenic and thus different from those of the earlier development stages of mobile zones, obviously should be different in its metallogenic characteristics, possibly containing useful minerals lacking in Cambrian ultrabasic intrusions.

It is obvious that the question of younger, Hercinian, ultrabasic intrusions of Gornyy Altai is fairly complicated, involving as it does a number of general problems of magmatism and metallogeny, of great theoretical and practical importance. Obviously a proper solution of this problem involves more than a dictum, however categorical. What is needed is the evidence of extensive factual material, and its comprehensive analysis.

As a study of ultrabasic intrusions of the Altai-Sayan folded province has been our task of many years, we[1] gave our most serious consideration to the reports of ultrabasics in an allegedly magmatic contact with the Devonian of Gornyy Altai, and we carried out detailed investigations in the proper area. Their results are set forth below.

[1]A group consisting of G.V. Pinus, I.M. Volokhov, and the author, who have carried out a special study of the geology of the Tuva ultrabasics 18 and have just completed a review of the Altai-Sayan ultrabasic geology, as a whole.

FACTUAL DATA

TEREKTIN RANGE OF CENTRAL ALTAI

There are three localities in the Gornyy Altai where ultrabasics are emplaced in Silurian and Devonian beds. The most spectacular of them is the Terektin range region, particularly the headwaters of the Kaznakhta River, the left-hand tributary of the Katun' River. This region was previously studied by V.P. Nekhoroshev [15], and in more detail by A.S. Yegorov [8], both noting the closest association of the ultrabasics with the oldest rocks, and asserting their Lower Paleozoic age. M.K. Vinkman and A.B. Gintsinger reported their recent observations in that area, of active magmatic contacts of ultrabasics, not only with the oldest rocks, but with Silurian and Devonian rocks, as well. According to them, these are best seen at the headwaters of the Kaznakhta River, along springs Kara-Uyuk and Kyzyl-Uyuk, where offshoots of ultrabasics into Devonian sandstone occurs, and where Devonian rocks in contact with the ultrabasics are silicified and replaced by magnesite and dolomite, with the formation of quartz-carbonate rocks carrying fuchsite and chromite of the Ural type termined listvenite. In the opinion of those authors, "this clearly suggests an intrusive contact of the ultrabasics and Devonian deposits." Similar contacts, accompanied by listvenite, are noted in the upper reaches of the Kucherlu-Ayry River of the Malyy Eloman River system, and in the headwaters of the Nizhnyaya (Lower) Kotanda, i.e., along a northwestern extension of a regional fault associated with the Kaznakhta locality [7].

In 1955, I.M. Volokhov, B.N. Lapin, and myself, studied the Terektin range region in some detail in the area of the Kaznakhta River, and made a geologic map of the area at a scale approximating 1:25,000.

First of all, our study has confirmed the association of ultrabasic massifs of the Terektin range with the Terektin regional fault zone only, exactly as noted by A.S. Yegorov, and with the Cambrian greenstone volcanic rocks, whose blocks are the structural component of this zone. Very conspicuous is the absence of ultrabasics in the areas of development of the Chuya Silurian formation and in the Devonian (Fig. 1).

In the Kaznakhta headwater area, the Terektin regional fault zone, according to our data, is especially complex in structure. Here, hemmed between the Terektin Proterozoic metamorphic schist of the high southwestern side of the fault, and the Chuya Silurian formation of sandstone and limestone of the low northeastern side, there lie large tectonic blocks of Cambrian and

Fig. 1. Map of ultrabasic massifs distributed throughout the regional Terektin fault zone, in Central Asia (after V.A. Kuznetsov).

1-Terektin Proterozoic metamorphic schist; 2-Cambrian greenstone volcanic-sedimentary sequence; 3-ultrabasics; 4-Silurian sandstone, shale, and limestone; 5-multicolored Devonian effusive-sedimentary sequence.

Devonian rocks (Fig. 2).

There is no need to pause for a description of the metamorphic schist of the hanging wall, nor for the Silurian Chuya formation of the downthrown side of the fault. Of much more interest are the Cambrian and Devonian of that structure, and the ultrabasic massifs. Our study has led to the following conclusions as to the composition, the extent, and the position of these bodies.

The composition of the Cambrian rocks is very suggestive. It is dominated by porphyritoids, gray-green to black-green, strongly chloritized and amphibolitized, and formed under dynamometamorphism, at the expense of diabase and augite porphyries; also by porphyritic tuffs, strongly schistose and turned to chlorite schist. Besides that, black metasomatic quartzite, gray dolomitized crystalline limestone, in small lenses, and metamorphic rocks associated with serpentinites, are present; black chloritic rocks, light-gray talc schist, and listvenite are also present. Although no Cambrian fauna has been found in the limestone, the general aspect of this greenstone sequence is such as to make possible its fairly certain correlation with sequences of similar make-up which carry elsewhere -- namely, in the Chagan-Uzun region of southeast Altai and in the adjacent regions of Tuva -- a Cambrian fauna and definitely belong to the base of the Cambrian.

A Cambrian greenstone sequence of this composition is traced in a NW band trending across the subject area, from the headwaters of Kyzyl-Uyuk stream, in the northwest, to those of Kara-Uyuk, in the southeast.

It is in this greenstone sequence that all of the ultrabasic bodies known here are located, including the large Kaznakhta ultrabasic massif. Other than that, a small serpentinite lense was found in the Proterozoic Terektin metamorphics. No instances of ultrabasic bodies within the Silurian and Devonian have been found.

The Kaznakhta ultrabasic massif is a sizable body, up to 2 km long and 0.4 km across. In shape, it is a nearly vertical lense. It is accompanied by a series of small, also steeply-inclined lenses. All of them have their long axes oriented NW,

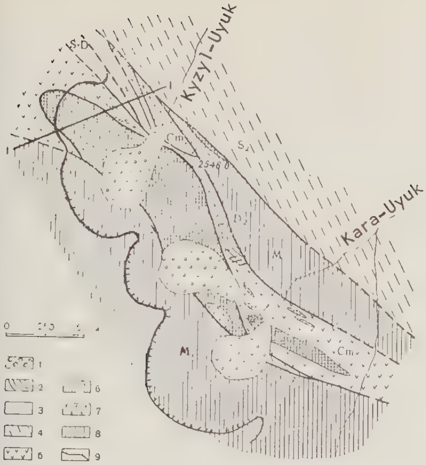

Fig. 2. Geologic structure of the Kaznakhta headwater locality, Terektin range, Central Altai. By V.A. Kuznetsov, I.M. Volokhov, and B.N. Lapin.

1-Morainic deposits; 2-Middle (?) Devonian light-gray sandstone; 3-Devonian violet, gray, and green sandstone, slate, and tuff; 4-Upper Silurian sandstone, slate, and limestone; 5-Cambrian greenstone volcanic-sedimentary rocks; 6-Cambrian serpentinite; 7-diorite; 8-Proterozoic meta-shale; 9-erosion patterns of escarpments and cirques.

consistent with the prevailing trend of the Cambrian sequence lodging them and with its internal structure; i.e., they are related bodies which appear to have undergone folding as a part of the enclosing rock.

The petrographic composition of the Kaznakhta massif is very simple and monotonous. Regardless of their size, all of the massifs are made of serpentinite; even within the large massif, there are no traces of unaltered magmatic rocks. Apoperidotite and chrysotile-antigorite varieties predominate among the serpentinite. The rocks commonly are strongly schistose and abound in veins of gem serpentine, serpophyte, and peculiar pink talc. In the northwestern Kaznakht massif, there is a well-known deposit of chrysotile-asbestos, studied by O.M. Ansheles [1], in his time, and by V.P. Nekhoroshev [15].

The chemical composition of serpentinite from samples analyzed by us is in no way different from that of the Cambrian ultrabasics of the Altai-Sayan province.

The manifestations of contact metamorphism, as in most such cases, are very weak, usually being camouflaged by the products of superimposed hydrothermal metasomatism which affect both the enclosing rocks and the adjoining serpentinite. Fringes of chlorite and talc schist and listvenite have been observed at some contacts here.

The serpentinite of the Kaznakhta massif is pierced by strongly-altered bodies of uralitic gabbro-diorite, and in one instance by a small stock of fresh hornblende diorite.

Thus, in the petrographic and chemical composition of the component rocks, in the composition of the associated metamorphics, and in the position and morphology of their bodies, the Kaznakhta ultrabasics, like those of the entire Terektin range, are analogues of the ultrabasic intrusives of the Southeast Altai and the adjacent regions of Tuva and West Sayan, whose Cambrian age is agreed upon, by all investigators. Especially convincing in this respect is a consistent spatial association of the Terektin ultrabasic massifs with the Cambrian greenstone volcanic-sedimentary formation, the relationship between their respective structures, and the similarity in the character and degree of their metamorphism. All of that obviously suggests that the ultrabasics were folded simultaneously with the Cambrian sequence; i.e., they are Lower Cambrian in age and are involved in the Terektin fault zone together with the Cambrian beds as passive tectonic blocks.

The Devonian is poorly developed in the Kaznakhta headwaters, where it is represented by two small, isolated tectonic blocks. One of them is located on the west slope of the Kyzyl-Uyuk valley. It is made chiefly of violet, brown, and gray-green sandstone, tuff, and shale -- all non-metamorphosed and sharply differing from the greenstone Cambrian rocks. According to A.S. Yegorov [8], this multicolored Devonian sequence has, at its base, thick conglomerate with pebbles of Cambrian metamorphic schist and greenstone rocks, and rests directly upon the Cambrian. In the subject area, multicolored Devonian rocks occur in a faulted block, on the west bank of the Kyzyl-Uyuk, as shown on cross-section, Fig. 3.

Another block of presumably Devonian rocks is located on the watershed between the Kyzyl-Uyuk and Kara-Uyuk streams (more precisely, on the steep slope facing the Kara-Uyuk, south of a summit with a bench mark of 2,548 m). Here, a sequence of well-stratified sedimentary rocks occurs: light-gray sandstone with microquartzite pebbles, gray-green and violet shale, and light-gray calcareous sandstone. Their total thickness is about 60 to 70 m, and they rest, comparatively flat, upon an extensively dislocated Cambrian sequence, including serpentinite. Judging by their composition

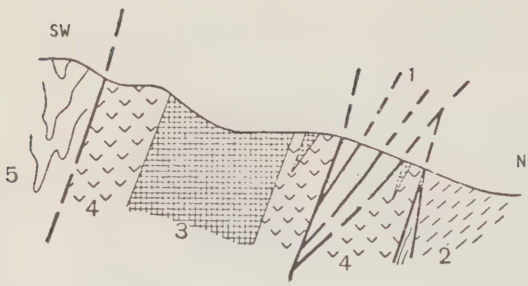

Fig. 3. Cross-section of the Kaznakhta headwaters, along line I-I, Fig. 2. (west slope of the Kyzyl-Uyuk valley).

1-Devonian violet, gray, and green sandstone, shale, and tuff; 2-Upper Silurian sandstone, shale, limestone; 3-serpentinite; 4-Cambrian greenstone volcanic-sedimentary rocks; 5-Proterozoic Terektin metamorphic schist.

and position, these rocks are of a younger, probably Middle Devonian age. This sequence is meridionally oriented; i.e., at an angle to the strike of the tectonic zone, as a whole. The beds dip to the east, at 40 to 50°. An erosion remnant, this Devonian sequence is cut off by a fault, to the northeast, where it contacts the Terektin metamorphic schist. Its normal stratigraphic contact with the underlying Cambrian rocks is also complicated by a small fault, along which, incidentally, the Devonian sandstones are in local contact with the Kaznakhta serpentinite.

The fault planes, separating the noncontemporaneous components of the Terektin tectonic zone, are approximately parallel, dipping steeply to the southeast, thus qualifying this zone as a complex thrust or a steep thrust block of a scaly structure. Its present aspect apparently developed during the Hercinian stage of tectogenesis. In a number of localities, the fractured zones within the fault zone carry evidence of mineralization by silicification and especially by the development of metasomatic, vein quartz-carbonate rocks, locally with hematite, pyrite, and certain other sulfides, reminiscent of listvenite. In other localities of the Terektin zone, antimony and mercury ore formation is related to the quartz-carbonate veins. It is fairly obvious that low-temperature quartz-carbonate mineralization took place along the shattered zones, superimposed over all of the Cambrian and Precambrian formations, including the serpentinite, and without either spatial or genetic connection with the intrusive massifs, including the ultrabasics, exposed on the eroded surface.

These are, in brief, the results of our investigations of the subject area. Clearly, we have not found any evidence of active magmatic emplacement of ultrabasic intrusions in the Devonian, either in the Kaznakhta locality or anywhere in the Terektin range. Nor have we found any ultrabasic massifs, different either in their form, position, or the composition of their components, from the Cambrian ultrabasics well-known in a number of the Altai-Sayan regions. On the contrary, what we did find in the Kaznakhta locality was typical for Cambrian ultrabasics, concordant linear bodies of serpentinite, clearly subordinate to the structure of the emplacing Cambrian rocks, and dislocated and metamorphosed with them. Thus, according to our data, there is no evidence for a post-Devonian age of the ultrabasic intrusions in the subject area; on the contrary, there are a number of convincing facts suggesting its ancient Cambrian age.

The question arises: what kind of field evidence did M.K. Vinkman and A.B. Gintsinger have to support their conclusions? In order to deal with this question, and to expose the character of this evidence, we shall cite a few instances of divergence of the true geologic situation and the geologic sketch as drawn by these authors. With this map and their notes, we have established the following facts.

On the west bank of the Kyzyl-Uyuk, where the Vinkman-Gintsinger map shows an ultrabasic offshoot into a Devonian sequence, the very detailed observations by I.M. Volokhov and B.N. Lapin revealed a tectonic block of Cambrian greenstone porphyry and tuff, enclosed by faults with zones of shattering. There is a small serpentinite lense in the greenstone porphyry. There is no direct contact of the serpentinite and Devonian rocks. The Cambrian block is only 200 m across and is in a fault contact with an Upper Silurian sequence, on one side, and with Devonian sandstone on the other. A cross-section of this locality is given in Fig. 3. Obviously, the greenstone Cambrian volcanics were taken for ultrabasics, and tectonic contacts for magmatic.

In another locality, on the watershed between the Kyzyl-Uyuk and Kara-Uyuk headwaters (more precisely, on the rocky slope facing the Kara-Uyuk, 200 to 300 m south of a summit with a bench mark of 2,548 m), i.e., just where M.K. Vinkman and A.B. Gintsinger note, in their opinion, the best-expressed, magmatic contact of ultrabasics and Devonian rocks, we found an essentially

ferent situation. To be sure, there is a [direct] serpentinite-Devonian sandstone contact here, but it is a tectonic and not an intrusive one; the contact is linear and without any offshoots into the sandstone. There is a distinct zone of shattering along the contact, where the serpentinite is strongly schistose and the sandstone shattered and fractured. Along the shattered zone, both the sandstone and serpentinite have undergone metasomatic carbonatization, with the fractures carrying veins of quartz and carbonates cementing the tectonic breccia. Moreover, the Devonian sandstone is cut by small cross-faults, vertical and trending northeast, and also carrying quartz-carbonate veins cementing the tectonic breccia. It is quite evident that this quartz-carbonate mineralization of the shattered zones has no genetic connection with the ultrabasic intrusion, and should not be regarded as a result of contact metamorphism resulting from it. A structural sketch of this locality is given in Fig. 4. Obviously the structural contact here was taken for the intrusive one, with the quartz-carbonate mineralization along the shattered zone, erroneously taken for contact metamorphism of the ultrabasic intrusion.

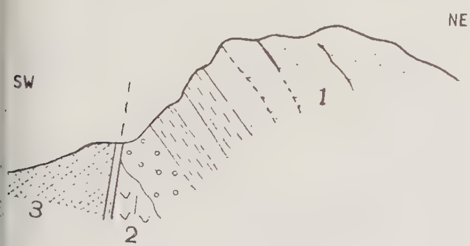

Fig. 4. Position of the Middle (?) Devonian along the slope of the Kara-Uyuk valley.

1-Middle (?) Devonian light colored sandstone and shale; 2-Cambrian greenstone porphyry; 3-serpentinite.

Finally, in the third locality within the rocky watershed between the headwaters of two Kara-Uyuk tributaries, where the Vinkman-Gintsinger map shows still another instance of a magmatic contact between ultrabasics and Devonian rocks, the latter are altogether lacking. An excellent outcrop here shows a greenstone Cambrian volcanic and sedimentary section represented chiefly by chloritized diabase porphyry, porphyritoids, tuffa-schist, black quartzite, gray metamorphosed limestone, and other typically Cambrian ophiolitic rocks. It is in this sequence, and not in the Devonian rocks, as the Vinkman-Gintsinger work has it, that one large and two small serpentinite bodies are emplaced.

It appears that the observations by M.K. Vinkman and A.B. Gintsinger, in the Kaznakhta locality, were too superficial to enable them to decipher its complex tectonic structure. By not looking into the petrography of the rocks, they committed gross errors, namely by having taken the Cambrian effusive and sedimentary rocks, in some localities, for ultrabasics. Finally, an erroneous assumption of an alleged contact-metasomatic origin for a listvenite type quartz-carbonate was taken as a basis for the assumption of a magmatic contact and a younger age for the ultrabasics.

The authors emphasize that "the formation of quartz-carbonate, ankerite-magnesite-dolomite or albitized and carbonatized rocks, at the contact of ultrabasics with sandstone, shale, marl, and acid effusives, clearly suggests an intrusive contact between the ultrabasics and Middle Devonian-Upper Devonian deposits" [7]. It is well known, however, that the idea of a contact-metamorphic origin for listvenite has been abandoned by the majority of the investigators. The students of listvenites from a number of regions, particularly the Urals, have shown the listvenites to be heterogeneous formations, the products of reworking of many different, basic intrusives and effusives as well as the ultrabasics, by hydrothermal carbonate solutions of various origin, including those connected with acid granitoid intrusions [5, 10, 20]. The presence in listvenite of magnesite, and especially of chromite, which is a relict magmatic mineral, is a proof that this listvenite is of an apoultrabasic type, i.e., formed at the expense of an ultrabasic rock [3, 4]; without, however, solving the problem of a genetic connection between the listvenitizing solutions and solutions related to this intrusion. Our study in a number of areas, specifically in Tuva, have shown the presence of metasomatic and hydrothermal listvenite which had originated as a result of a hydrothermal activity much later than the ultrabasic intrusions. The presence of chromium mica-fuchsite is explained in those instances by the presence of chromium-enriched ultrabasic rocks, in the path of the hydrothermal solutions [18].

In the light of the above discussion, one is naturally inclined to doubt the statement of the presence of alleged listvenite with chromite and magnesite, in the Kaznakhta locality, as appearing at the expense of sedimentary Devonian rocks; and of the presence of Upper Silurian limestone at the headwaters of the Nizhnyaya Kotanda, penetrated by chromite inclusions, at their contact with the ultrabasics [7]. In these instances, too, the authors, obviously not trained in the specific problem of the geology of ultrabasics and associated metamor-

phic formations, have misread and misinterpreted the geologic situation.

Thus, the results of our special study positively refute the conclusions of M.K. Vinkman and A.B. Gintsinger on the manifestation of a young Hercinian intrusion in the Terektin range of Central Altai. Even more erroneous is the conclusion that the observations by these authors refute the previous ideas of a Cambrian age for the Gornyy Altai ultrabasics, as a whole.

OTHER REGIONS OF THE GORNYY ALTAI

Another region of the alleged post-Cambrian ultrabasics is the northern part of Gornyy Altai, namely a locality on the Kyrkyla River, a tributary of the Kuyacha River, in the Peschanaya River system. This locality has been long known for its massive serpentinite in a sand and shale sequence assigned to the "Cambro-Silurian." The M.K. Vinkman communication [6] has it that the age of the serpentinite-bearing section is now defined by an Upper Silurian fauna, and that a certain post-Silurian intrusion has been recognized in that area. This circumstance, in the opinion of that author, refutes the idea of a Cambrian age for the Gornyy Altai ultrabasics, in general.

Our own subsequent investigations (by G.V. Pinus and myself, in 1949) have not confirmed M.K. Vinkman's assertions. We have found somewhat different geologic conditions in the Kyrkyla area. The sand and shale sequence which carries the serpentinite bodies is completely unfossiferous and is exposed only in the middle of an anticlinal structure where it unconformably underlies sandstone and limestone, assigned by their organic assemblage to the Upper Ordovician. This means that the age of the serpentinite-bearing sequence of the Kyrkyla River cannot be Upper Silurian, as M.K. Vinkman believed, but is either Upper Ordovician or, more probably, Cambrian. The structure of the area, according to our data, is given on Fig. 5. The ultrabasics of the Kyrkyla River are represented by apo-peridotite serpentinite, common in the Cambrian ultrabasic scheme. They are located along a direct continuation of an ultrabasic belt whose Cambrian age is unquestionable. Therefore, there is no good reason for the separation of the Kyrkyla serpentinite group as an individual post-Silurian ultrabasic intrusion, let alone the assumption that the observations in the Kyrkyla area refute the idea of a Cambrian age for the Gornyy Altai ultrabasics, as a whole. One of the erroneous premises which led M.K. Vinkman to the above conclusions, was her lumping into a single ultrabasic group, the serpentinite massifs, and the basic intrusive massifs of the gabbro series. Obviously, it was not taken into consideration that gabbroid intrusions of the North Altai are of a different origin and a different age; more specifically, post-Silurian gabbro intrusions are indeed known, but they have no connection with the ultrabasic intrusion.

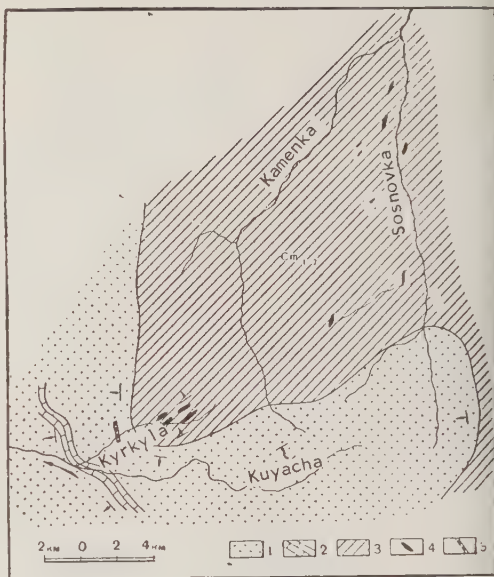

Fig. 5. Structural map of the Kyrkyla River area, northern Gornyy Altai.

1-Upper Ordovician sand and shale sequence; 2-Upper Ordovician-Lower Silurian limestone; 3-Cambrian effusives and schist; 4-serpentinite; 5-gabbro and diorite.

Finally, the third region where younger ultrabasic intrusions were suspected, is the Kuray range of southeast Altai. Cambrian ultrabasic intrusions have long been known in that area. Now, a recent communication speaks of ultrabasics cutting the Upper Devonian sediments in one of the northern Kuray spurs (a more precise location is not given) [19]. A short communication on this subject contains very few factual data, which hampers an evaluation of it; however, the author's mention of a localization of the ultrabasic massifs, in that area, in a great fault zone, is interesting. Although the communication points out a contact between the intrusive ultrabasics and the presumably Devonian rocks, the fact of the ultrabasics' localization in a fault zone puts a doubtful light on the author's conclusions as to magmatic contacts and a post-Devonian age of the ultrabasics. According to many investigators, more specifically the latest data by I.F. Pozharisskiy and myself, the Kuray range has a very complex tectonic structure. Along one of the greatest fault zones,

ented parallel to the range's axis, there s a broken belt, tens of kilometers long, ultrabasic massifs. The latter are always sociated with the rocks of a volcanic and dimentary Cambrian greenstone sequence, ming with them structural blocks as com- nents of the tectonic zone. Such blocks of mbrian rocks carrying ultrabasic massifs, mmed in between the Silurian and Devon- , were observed, specifically, in the east ray range, along the Bol'shaya Kokura ver, at its entrance to the Sargoga steppe; the upper course of the Malaya Kokura d Uzun-Oyuk Rivers, i.e., within the zone e extension of which includes the area of I. Rodygin's study. Therefore, there are asons to believe that in this area as well, e ultrabasic massifs are associated with mbrian greenstone, and that their Devonian ntacts are tectonic rather than the mag- atic, as in other Kuray localities. This oblem appears to be in need of more study; wever, it can be stated now, that the esence of young Hercinian ultrabasics in e Kuray range is not proved and, in the ght of data extant, appears to be hardly obable.

SUMMARY

The erroneous nature of the finding of ung Hercinian ultrabasic intrusions in var- us areas of the Gornyy Altai has been ex- sed by a special study carried out there. turned out that the communications had en based on superficial and erroneous servations. The presence of Hercinian trabasic intrusions in Gornyy Altai has not en confirmed by field data. The Gornyy ltai ultrabasic intrusions are typical pro- icts of magmatism of the early stages of evelopment of mobile zones, in this case e Caledonian folded structures of the ltai, and are Cambrian in age. The Cam- rian ultrabasic intrusions of Gornyy Altai, ke the contemporaneous ultrabasic intru- ions of the adjacent Altai-Sayan folded pro- ince, originated and were distributed ccording to certain definite patterns. Asso- iated with them is a complex of useful min- rals. A fixing of the age and regularities f distribution of the Gornyy Altai ultrabasic itrusions is of great practical significance, ecause it would facilitate a proper evalua- ion of the prospects and a rational approach o the search for useful minerals associated ith these intrusions.

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West Siberian Affiliate,

U.S.S.R. Academy of Sciences,

Novosibirsk.

Received December 14, 1956

BRIEF COMMUNICATIONS

NEW FINDINGS AND THE STRATIGRAPHIC POSITION OF TOLMACHOVIA CONCENTRICA KOBAYASHI (CLASS CRUSTACEA) ROM THE ORDOVICIAN OF EAST SIBERIA

by

V.V. Lyubtsov

The Ordovician of East Siberia often carries small kernels and imprints, reminiscent f lamellibranchs (see Fig. 1).

As a result of recent years' work in the orthern region of the Yakut A.S.S.R., a rge collection of such fossils has been ssembled. In 1952, they were found by .I. Nikiforova, on the Moyero River; 1954, y A.A. Vysotskiy on the Khantayka River; 1956, by G.M. Pokrovskiy on the Alakit iver and by E.P. Markov on the Kyulyumba iver; in 1955, by V.V. Lyubtsov on the lorkoka and Markha Rivers. Despite their umber, these fossils did not attract much ttention; therefore, their significance and ystematic position remained obscure. They ere erroneously taken for unidentifiable ernels of ancient lamellibranchs.

As a result of processing of the collected aterial, it has been established that these ossils belong to a fairly rare and peculiar pecies, Tolmachovia concentrica, established by B. Howell and T. Kobayashi, in 1936 [2]. This species belongs to class Crustacea, subclass Eucrustacea, supergroup Brachiopoda, group Notostraca, family Riberidae, genus Tolmachovia.

The generic name was given after I.P. Tolmachev, who had first found these fossils in the Ordovician of the Moyero River. A poorly substantiated assignment by the authors of T. concentrica to the Notostraca group must be mentioned here.

Fig. 1

a-kernels of Tolmachovia concentrica shells, natural size, both sides; b-same, X 3; c-numerous molds of T. concentrica in limestone.

The representatives of this group are characterized by an elongated body, with a flat dorsal shell. It appears that T. concentrica had a bilaterally-symmetrical body, probably covered by a bivalve shell. In Tsittel's well-known manual [1], such forms are united into tribe Conchostraca. Probably, it would have been more correct to relegate this species to the Conchostraca tribe, although the poor state of preservation of the material makes it impossible to learn more of the interior structure of the valves, and establish the systematic position of the object.

B. Howell and T. Kobayashi assign the deposits of T. concentrica findings by I.P. Tolmachev, without much justification, to the Middle Ordovician. As a result of new data on the Ordovician stratigraphy of East

Siberia (All-Union Geol. Inst., All-Union Aerogeological Trust), it has been established that this form is associated not with the Middle Ordovician but rather with the Chun' stage of the Lower Ordovician. Everywhere T. concentrica occurs in beds with a typical gastropod fauna: Ophileta cf. complanata Ulr. et. Sc., Palaeacmea humilis Ulr. et. Sc., Tryblidium cf. nucteis Billings, Archinacella cf. subrotunda Ulr. et. Sc., Eccyllomphalus aff. triangulus Ulr. et. Sc.; brachiopods: Angarella lopatini Assat.; nautilides: Proterocameroceras brainerdi Whitfield, Endoceras motrealense Ruedeman -- which makes it possible to assign these beds to the Chun' stage of the Lower Ordovician, with certainty.

Of especial interest is a wide lateral and narrow vertical distribution of T. concentrica, throughout the Ordovician of East Siberia, which makes it an outstanding index fossil. The peculiar shape of T. concentrica molds, and its frequency, facilitate an immediate recognition of the Chun' stage beds and their tracing over great distances.

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All-Union Aerological Trust
U.S.S.R. Ministry of Geology and Mineral Conservation,
Moscow

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FAUNA OF LOWER SARMATIAN CLAY FACIES FROM TRANS-CARPATHIA AND KARABUGAZ AREA

by

G.N. Grishkevich and L.A. Nevesskaya

The Lower Sarmatian of the north Karabugaz shore, on one side, and of the Trans-Carpathia, on the other, is represented by clay sediments carrying a very similar fauna:[1]

As seen from the lists, the fauna is nea[rly] identical in both regions. Especially signifi[i]cant is the presence of Cardium transcarpaticum Grischk. [3] which also occurs in Moldavia, in the Lower Sarmatian clay; and in the Lower Sarmatian clay of Georgia (Ye. K. Vakhaniya collection).

Apparently this faunal complex was indig[e]nous to the Middle Sarmatian sea where the water was quiet and fine sediments were deposited. Such conditions could have existed either at some depth or in comparatively shallow areas without much influx of terrige[-]nous material. The second was probably tru[e] for the Karabugaz area and the Trans-Carpathia. A shallow water of clayey shell beds of a shallow-littoral type, locally changing to clean shell beds (Kafabugaz area [2]). They contain Ervilia pusilla dissita Eichw., Tapes vitalianus Orb., T. tricuspi[s] Eichw., Donax lucidus Eichw., Cardium ust[-]jurtense (Andrus) Koles., C. vindobonense Lask., C. plicatum Eichw. In the Trans-Carpathia, numerous well-preserved plant remains occur with the shells: leaves of beech, alder, and nut trees. Locally, the shells rest directly on leaves. In many instances, the fossiliferous clay contains unconsolidated sand with well-preserved cross-bedding.

Thus, Middle Sarmatian time appears to have witnessed, in the Trans-Carpathia and the north Karabugaz shore, rather shallow stretches of sea where fine clayey sediments were deposited. A similarity in the environment brought about a similarity in organic life. However, even under such an assumption, the question remains open as to whether this similarity in the fauna of two distant regions was brought about by migration alone.

Cardium pium Zhizh. is fairly well developed in the Trans-Carpathian Lower Sarmatian clay, with its origin traceable from C. transcarpaticum Grischk., as confirmed by the presence of temporally transitional forms (Fig. 1-a). At the top of the sequence both of these species occur together, no longer connected by transitional forms.

The same phenomenon is observed in the Karabugaz. Near the base of the Middle Sarmatian, C. transcarpaticum Grischk. begins to change in a definite direction; main ribs become higher than the intermediate ones, and their alternation becomes

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[1] Trans-Carpathian material has been processed by G. N. Grishkevich; the Karabugaz material -- by L. A. Nevesskaya.

North Karabugaz Shore	Trans-Carpathia
Clay and marl with:	Clay with:
ırdium transcarpaticum Grischk.	Cardium trascarpaticum Grischk.,
pium Zhizh. (base of M. Sarmatian only)	C. pium Zhizh. (top of L. Sarmatian -- base of M. Sarmatian)
plicatum rybnicense subsp. nov. (rare)	C. vindobonense (Partsch) Lask.
ustjiurtense (Andrus.) Koles.	C. lithopodolicum Dub.
lithopodolicum Dub.	C. sarmaticum Barb.
	C. repentinus sp. nov. (rare)
	C. incurvatum Koles. (rare)
·pes naviculatus R. Hoern.	T. naviculatus R. Hoern.
vitalianus aksajicus Bog.	T. vitalianus aksajicus Bog.
vilia pusilla dissita Eichw. (rare)	E. pusilla dissita Eichw. Numerous at top of Up. Sarmatian
pusilla andrussovi Koles.	E. pusilla andrussovi Koles
ısculus naviculoides maximus subsp. nov.	M. naviculoides maximus subsp. nov. (frequently)
actra sp. (aff. andrussovi Koles.)	Mactra andrussovi Koles. Numerous at top of Up. Sarmatian
	M. eichwaldi Lask.
	M. eichwaldi pleschakovi subsp. nov.
	M. eichwaldi rotunda subsp. nov.
	M. conglobata sp. nov.
	M. praenaviculata sp. nov.
ora reflexa Eichw. (numerous only at the very base of Sarmatian)	Abra reflexa Eichw. (numerous only at the base of Lower Sarmatian)
:teocina sp.	Acteocina lajonkaireana Bast.
	Trochus angulatus Eichw.
	Tr. angulatosarmates Sinz.
	Mohrensternia inflata M. Hoern.
	Cerithium mitrale Eichw.
	C. nodosoplicatum M. Hoern.
	C. rubiginosum (Eichw.) Dub.

ore regular. Thus the typical features of ırdium pium Zhizh. emerge and become ore enhanced in higher levels, finally leadg to the emergence of a typically-formed ecies (Fig. 1-b).

The same phenomenon is observed with her forms as well. Thus, Tapes naviculas R. Hoern. is connected with T. vitalianus ıb., particularly with its sub-species vitalianus aksajicus Bog. This transition traceable both in the Karabugaz and in the rans-Carpathia. The same is true for vilia pusilla dissita Eichw. and E. pusilla drussowi Koles., although here we deal th the origin of subspecies rather than of ecies.

It is difficult to conceive of the similarity tween the Karabugaz and the Transırpathian Lower Sarmatian faunas as being ıe solely to migration; such an assumption ould imply a continuous faunal exchange, a igration not only of the initial and terminal forms, but of those in between as well, which is rather improbable.

It appears that a migration of the original forms was supplemented by a parallel development which proceeded in similar conditions in two distant areas. In this process, the evolution of Tapes naviculatus R. Hoern. and Ervilia pusilla andrussovi Koles. from T. vitalianus aksajicus Bog. and E. pusilla dissita Eichw., respectively, is best explained by a change of the latter forms to a slimy bottom environment type, since T. vitalianus aksajicus Bog., and particularly Ervilia pusilla dissita Eichw., are most common in shell limestone and sand.

The causes of the evolution of C. pium Zhizh. from C. transcarpaticum are more complicated, because here we deal with an evolution without perceptible changes in the sediments, without any facies' change. The appearance of a new species, in this case, is determined not as much by a change in

local ecologic conditions, as by the development of the entire basin and its fauna. Assuming a parallel evolution of very close forms from a common ancestor, in different regions, the question arises: are we dealing with a single species or should similar and undistinguishable morphologic forms be assigned to different species?

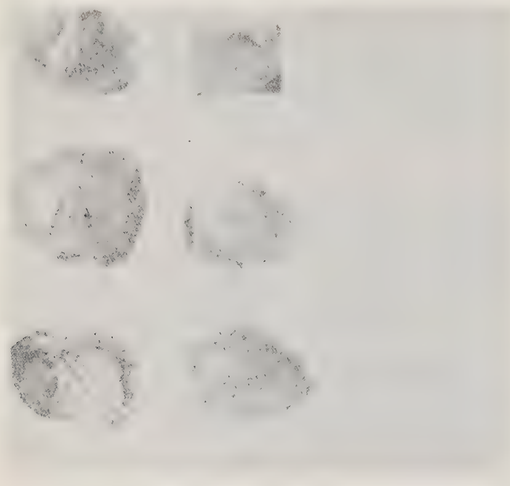

Fig. 1. Series, C. transcarpaticum Grischk. - C. pium Zhizh.

a-Trans-Carpathian Lower Sarmatian; b-Lower Sarmatian base of Middle Sarmatian, Karabugaz area.

It would be very interesting to study in detail the Lower Sarmatian clay facies, in intermediate regions: in Moldavia, Ukraine, and the Caucasus. That possibly might furnish additional data, helpful in the solution of this problem. As yet, this is not feasible.

The finding in the Lower Sarmatian, of Cardium transcarpaticum Grischk. sheds some light on the origin of the Middle Sarmatian C. barboti R. Hoern. and C. suessi Barb., which has remained obscure. The first species is similar to C. transcarpaticum Grischk., in the character of its rib structure, differing from the latter in its trapezoidal shape and strongly protruding apex; it probably evolved from the latter, while C. suessi Barb. is similar with C. pium Zhizh. but differs from the latter in a greater number of ribs. It is very possible that both C. suessi Barb. and C. pium Zhizh. evolved from C. transcarpaticus Grischk. or related forms. Their similar features (sharp distinction between main and intermediate ribs) is a probable result of convergence. A new light is also shed on the origin of Cardium subfittoni Andrus. which is likewise related to C. transcarpaticum Grischk. rather than to C. fittoni Orb. [1]. The first two species have a similar rib structure and a very similar shell form, although C. transcarpaticum Grischk. lacks the long rib spicules and does not have as many intermediate ribs.

Fig. 2. A scheme of probable phylogenetic relationship within the group C. transcarpaticum Grischk.

A similarity between the young specimens of C. pium Zhizh., on one hand, and C. plicatum Eichw. and C. fittoni Orb., on the other, is perhaps suggestive of a kinship between groups C. plicatum Eichw. and C. transcarpaticum Grischk.

C. transcarpaticum Grischk., a Lower Sarmatian newcomer from the west, proceeded to give rise to a number of new species (C. pium Zhizh., C. barboti R. Hoern., C. subfittoni Andrus., C. suessi Barb.), most of which, like their ancestor, were adapted to life on a slimy bottom, under quiet waters. The phylogenetic relationship between the species of group Cardium transcarpaticum Grischk. is shown on Fig. 2.

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Paleontological Institute,
U. S. S. R. Academy of Sciences,
Moscow

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KYNOV BEDS OF THE DEVONIAN IN BASHKIRIA

by

A. R. Kinzikeyev

According to the 1951 unified scheme for the Devonian, the Kynov beds of the Volga-Ural sedimentary province are characterized by an assemblage of brachiopods, Schizophoria ivanovi Tschern., Cyrtospirifer murchisonianus Vern. (non Kon.); ostacods, Cavellina devoniana Egor., Buregia zolnensis Pol., Uchtovia polenovae Egor.; and corals, Syringopora supragigantia var. pachitheca [1].

In Bashkiria, the Kynov beds are taken to include the section from the marker "upper limestone" bed to the base of the Sargayev beds as defined by brachiopods Hypothyridina calva Mark. (in litt.), Lamellispirifer novosibiricus Toll., and others. This interval is represented as a rule by greenish-gray to chocolate-brown argillite with beds of limestone and siltstone, commonly changing to thin lenticular sandstone.

In 1951-1954, the author carried out, at the Moscow Gubkin Petroleum Institute, under the direction of M. F. Mirchink, a structural study of the productive Devonian section of Bashkiria and adjacent lands. As a result of these investigations, it became possible to divide the composite Bashkirian productive section into 13 primary, two- or three-phase rhythms, including a three-phase rhythm in the so-called Kynov beds. These rhythms are as follows (reading upward): 1st rhythm -- a series of conformable a) "upper limestone" beds and their correlatives, b) beds of argillite and siltstone, c) sandstone beds (so-called Mikhaylov or Middle Kynov sandstone); 2nd rhythm -- a series of conformable a) so-called "Middle Kynov limestone" beds, b-c) overlying beds of argillite and siltstone; 3rd rhythm -- a series of conformable so-called "Upper Kynov limestone" beds, changing upward to argillaceous varieties. Deposits of the 1st primary rhythm rest, with a stratigraphic break, upon various horizons of the Givetian stage; those of each succeeding rhythm rest unconformably upon different horizons of the preceding rhythm.

A painstaking study of all available fauna, as correlated from outcrops of the primary rhythms, has shown each rhythm possessing its peculiar assemblage. Because of that, and also because of regional unconformities between the primary rhythms, these rhythms were taken as individual stratigraphic units. As it turned out, the 1st primary rhythm was lacking in the Kynov index fauna -- the brachiopods of group Cyrtospirifer murchisonianus. The limestone ("upper limestone") and the overlying argillite of the 1st primary rhythm carry a brachiopod assemblage: Atrypa pseudouralica Mikr., A. ex gr. tubaecostata Paeck., Jemenia tenuicostata Mikr., Productella ex gr. subaculeata Murch., and others; also ostracods, Indivisia schigrovskensis Pol., Buregia zolnensis Pol., B. egorovi Pol., Uchtovia polenovae Eror., and others (as identified by A. V. Vladimirova, V. N. Krestovnikov, M. F. Mikryukov, and others). The deposits of this rhythm are best developed in West Bashkiria. Their thickness there is 20 m.

The index forms of the Kynov fauna along the west slope of the Urals -- Cyrtospirifer murchisonianus Vern. (non Kon.) and Schizophoria ivanovi Tschern. -- first appear in the basal limestone of the 2nd primary rhythm, in the so-called "Middle Kynov" limestone. The deposits of this rhythm are best developed in north Bashkiria where the basal limestone of the 2nd rhythm are represented by pure varieties, attaining a thickness of 15 to 16 m. They carry an abundance of the above-named forms, the brachiopods of group Cyrtospirifer murchisonianus being, according to A. I. Lyashenko, close to Uchtospirifer nalivkini Ljasch. forms typical for the lower multicolored unit of the Timan Nefteol' formation [3, 4]. The deposits of the 3rd primary rhythm have a restricted distribution in north Bashkiria where Uchtospirifer timanicus Ljasch., Hypothyridina presemilukiana Ljasch., indexes for the upper multicolored unit of the Timan Nefteol' formation [1, 2] appear in them.

New field data, recently obtained within and without Bashkiria [3], fully corroborate the above statements. Specifically, the stratigraphic individuality of two lower primary rhythms is confirmed by the microfauna, as well.

All of that leads to the following conclusions:

1. The deposits now taken to be Kynov, in Bashkiria, are not correlative with those along the west slope of the Urals.

2. The deposits of the 1st primary rhythm -- from the base of the "upper limestone" to the base of the so-called "Middle Kynov" limestone -- are equivalent to the

Pashiisk beds of the west slope of the A.I. Lyashenko scheme for the central provinces of the Russian Platform.

3. The Kynov beds, in their most complete sections, may be divided into two individual stratigraphic units: a) Lower Kynov beds, characterized by a fauna of Uchtospirifer nalivkini Ljasch., Schizophoria kremsii Ljasch., and correlative with the lower multicolored unit of the Timan Nefteol' formation, and with the Archedinsk unit of the central Russian Platform, and b) Upper Kynov beds characterized by a fauna of Uchtospirifer timanicus Ljasch., Hypothyridina presemilukiana Ljasch., and correlative with the upper multicolored unit of the Timan Nefteol' formation and the Kikin unit of the central Russian Platform Devonian, as given by the A.I. Lyashenko scheme [3, 4].

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Ufa Petroleum Institute

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DIABASE OF THE DZHENTA RANGE AND KHATSAVITA RIVER, NORTHWESTERN CAUCASUS

by

S.S. Kruglov

In the summer of 1956, while undertaking a geologic study of the basin of the Laba River in the Northwestern Caucasus, V.N. Robinson and I came across some new exposures of diabase hitherto not described in the literature and not shown on any geologic map. The determination of the geologic age of this diabase is of considerable interest in the reconstruction of the history of magmatism in this part of the Greater Caucasus.

The outcrops are located in three separate points within the major Dzhenta syncline, made up of Lower Paleozoic metamorphic rocks. The southernmost exposure of diabase is located in the immediate vicinity of the highest point of the Dzhenta range, and presents a neck with diameter not over 1 m which pierces the lower volcanic and the marble intervals of Lower Paleozoic age. Another exposure of the same rock, a sill about 2 m thick, conformable with quartz-biotite schist of the upper metamorphic sequence of the Lower Paleozoic, is found about 4 km north of the Dzhenta range summit.

Finally, still farther north, in the headwaters of the Khatsavita River (right bank tributary of Malaya Laba), there is a dike of the same diabase, over 2 km long, striking sub-meridianally (N-20°-W), nearly vertical, and 15 to 20 m thick. Here, the diabase cuts the Middle Carboniferous coarse-grained, yellow-gray sandstone and light colored conglomerate and also conglomerate of an Upper Permian multicolored sequence.

Both macro- and microscopic study revealed a great similarity between these exposures. When fresh, they are dark gray with a greenish tint, fine grained, crystalline, having a massive texture and a fresh Cenozoic aspect. A characteristic feature is their uniformity in mineral composition, texture, and structure. Only at the immediate contact with the enclosing rock there is a narrow (10 to 20 cm) aphanitic band, nearly black, and showing a different composition under the microscope.

The principal components of the diabase are plagioclase and pyroxene. Auxiliary components are magnetite and biotite. Among the secondary components are chlorite and very small amounts of sericite. Also present are brown iron hydroxyls.

Plagioclase is represented by laths, microscopic elongate crystalline structures, 0.5 to 1 mm long. The largest individual grains attain 1.5 to 2 mm, in length. Plagioclase is polysynthetically twinned. Changes on the Fedorov stage assign it to basic andesite (no. 45). A more acid plagioclase (albite-oligoclase) is poorly developed along the periphery of the grains. The plagioclase grains are strictly idiomorphic with relation to other minerals of the rock. Its average content is 55 percent.

The pyroxene grains are irregular and stubby-columnar, up to 2.5 mm, and fill the space between the plagioclase laths. Perfect cleavage is present in two directions, at 88°. The mineral is very slightly brownish, without pleochroism. Strong double refraction (in the order of 0.030). Oblique extinction (cNg=38°). Biaxial mineral, 2V=+60 . The optical properties and the cross-section character (irregular octagon) suggest that this pyroxene is diopside. Its average content in the rock is 32 percent.

Biotite is distinctly subordinated, being represented by isolated small scales (up to 0.2 mm), strongly pleochroic in brown hues.

Magnetite, in isometric grains, 0.2 to 0.3 mm in size, accounts for no more than 5 percent of the rock.

Chlorite is represented by green scales and irregular aggregates up to 1 mm in diameter.

Sericite forms extremely small scales developed exclusively on plagioclase.

The diabase structure is ophitic, locally approaching poikilophitic.

The grain size in the contact fringe rocks of the diabases of the Khatsavita River and the Dzhenta range is 0.1 to 0.4 mm; structure prismatically-granular, determined by an irregular orientation of plagioclase prisms accounting for 70 percent of the rock. The space between them is filled with greenish aggregates of chlorite, iron hydroxyls, and carbonate. Pyroxene is fully lacking.

No exocontact alterations in the enclosing rocks have been observed.

These diabases are among rocks which are rare in the North Caucasus. The diabase of that region is characterized by amphibole as the colored mineral, but with a small amount or a total lack of monoclinic pyroxene. Furthermore, the known indigenous diabases are most often schistose and strongly metamorphosed.

The Psekokho Range diabase, within the Main Range and described by L.A. Vardanyants, is similar to those from the Dzhanta range and the Khatsavita River. Their lower age limit is taken to be Lower Permian; the upper age limit cannot be established for lack of stratigraphic data. However, no pebbles of these rocks have been encountered even in the uppermost beds of the Lower Permian, upper multicolored sequence.

It is quite probable that the analogues of these diabases might be the so-called "augite-chlorite" diabase studied by A.P. Lebedev from the Cherkess-Chegem and certain other areas of the Central Caucasus [2]. They are characterized by the great consistency in their petrographic, structural, and textural features, also by the thickness of their sills and dikes in the allegedly Precambrian, Paleozoic, Lower and Middle Jurassic rocks. According to A.P. Lebedev, they were formed during the pre-Callovian tectonic phase of the main Greater Caucasus folding.

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Caucasian Expedition of Moscow State,

M.V. Lomonosov University

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FROM THE HISTORY OF GEOLOGIC SCIENCES

MEMORABLE DATES FOR APRIL-MAY 1958

Review No. 21

TRICENTENARY OF THE ORIGIN OF THE TERM "GEOLOGY"

The term "geology" first appeared in print in the XV century, with a meaning quite different from the one assigned to it now.

In 1473, a book was published in Cologne by Bishop P. de Bury, called "Philobiblon" (Love of Books), where the author defined Geology as the entire complex of regularities and laws of "mundane" life as against theology, the science of the "transcendental" world and spiritual life. A hundred years later, the word "geology," as a science of rocks, minerals, and fossils, was used by the Italian naturalist Ulysses Aldrovandi (1522-1605), professor of logic and medicine at Bologna University. However, he used the term only on the frontispiece, and never mentioned it in the text. In publication of this work, in 1648, the title was fully changed and the word "geology" was not used.

In its modern understanding, the word "geology" first appeared in print in 1657. It was used by the Norwegian naturalist M.P. Escholt, in his work dealing with a great earthquake affecting all of South Norway (Geologia Norvegica, 1657). Michael Pedersen Escholt (died in 1669), a village priest of Akker, Norway, known for his work in many branches of natural history, published his book in Danish, in Christiania (Oslo).

Thus, the term "geology" in its modern sense appeared in the literature only in 1657.

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CENTENARY MEMORIAL FOR K. F. RUL'YE

Karl Frantsevich Rul'ye was born April 20 (8) 1814, in Nizhniy Novgorod, now Gor'ki. In 1833 he graduated from the Moscow Surgeons' Academy. Soon he changed to teaching mineralogy and zoology, while continuing his study of these subjects by practical acquaintance with nature and its laws. In 1842, K.F. Rul'ye became professor at Moscow University. His first paleontologic work was Geologic Excursions near Moscow. Later on he became one of the outstanding contemporary paleontologists.

Unlike most of his contemporaries, K.F. Rul'ye rightly believed that in paleontologic studies, it is not enough to deal with a single specimen, but one should strive to unravel the history of development of each form.

A correlation of the entire fossil assemblage as found at the same stratigraphic level of different localities, enabled him to establish the fact of multiple zoogeographic provinces. Specifically, he noted a large number of peculiar forms in the Upper Jurassic of the Moscow area, and he explained this by special climatic conditions of the region.

Subsequently, M. Neumeir showed in his works that these forms were typical for the boreal province.

K.F. Rul'ye was an ardent adversary of catastrophism and strove to emphasize the evolutionary nature of the development of the earth, with living organisms reflecting their environment. They "undergo a series of material and non-material changes, with each step an improvement over the preceding one." K.F. Rul'ye emphasized that an organism transplanted into a new environment is "reborn," so to speak, by losing many features proper to it in other physical and geographical environments. His works, establishing the relationship between an organism and its environment can be rightly regarded as a basis for paleoecologic study.

His study of the geology of the Moscow basin is the foundation for the Jurassic stratigraphy of the central part of European Russia. He described over 150 different

fossil forms from the Moscow Jurassic.

His abundant paleontologic material enabled him to subdivide these formations first into three, then into four stages. They came to be the standard section. His paleontologic and stratigraphic investigations are still valuable.

The lectures by K.F. Rul'ye, very progressive for that time in their views on the evolution of nature, attracted considerable attention in wide circles of Russian intelligentsia. On his initiative, the Moscow Society of Nature Students launched a magazine, Vestnik Yestestvennykh Nauk (Herald of Natural Sciences), for a promotion of advanced ideas in those sciences. Moreover, he wrote popular science articles for newspapers, whose content evoked the sharp protest of high church officials who eventually succeeded in stopping their publication.

K.F. Rul'ye died in Moscow, May 22 (10), 1858.

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CENTENARY ANNIVERSARY OF GERMAN PALEOBOTANIST AND GEOLOGIST H. POTONIES

Henry Potonies was born in Berlin, November 16, 1857. After graduating, in 1878, but while still a student in the University, he began to work as an assistant in the Berlin Botanical Garden and Botanical Museum (from 1880 on). In 1885 he changed to the phytopaleontologic division of the State geologic service. In 1891 he started his lectures on paleobotany in the Mining Academy and then in the university. He became professor in 1900.

His numerous paleobotanic works deal chiefly with Paleozoic flora. He laid the foundation for a detailed stratigraphic differentiation of the Carboniferous and Permian deposits of Germany.

His study of the vast flora material on the Silurian and Devonian of various regions enabled H. Potonies to recognize twelve plant complexes succeeding each other in the geologic history of the earth, in the time from the Silurian to the Triassic. These data were a basis for the development of the theory of plant evolution throughout the Paleozoic. Especially interesting are his works in plant morphology, analyzing this problem from a genetic point of view.

Of great scientific value are his works on the origin of organic fuels. He attempted to show that all coal measures were autochthonous, and he regarded sapropelitic accumulations as a source of oil. He proposed a ternary classification of fossil fuels: sapropelites, humus formations, and resin products. A number of his works deal with peat and a study of marshes.

His major works gained general recognition and were reprinted several times. His works on the origin of coal and on sapropelites were translated into Russian. H. Potonies was also known as the publisher of a popular magazine of natural history, Naturwissenschaftliche Wochenschrift.

He died October 28, 1913.

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SEVENTY-FIFTH MEMORIAL FOR V.O. KOVALEVSKIY

A founder of evolutionary paleontology, Vladimir Onufrievich Kovalevskiy was born August 14 (2), 1842, in the former Vitebsk Province. After graduating from the Law School in 1861, he spent two years in several cities of Germany, France, and England. Here he translated Lyell's Antiquity of Man, Brahm's Animal Life, Kelliner's Hystology, etc., which were published upon his return to Russia. In 1866, as reporter for a Petersburg paper, he went to Italy, to Garibaldi's army, from which he sent back articles sympathetic to the liberation movement. In 1869, he took another trip abroad, and studied natural sciences, chiefly geology and paleontology. From the material of his

study, he defended his thesis on fossil horses, first in the University of Jena (1872), then in Petersburg (1885).

Because of his progressive views, V.O. Kovalevskiy was unable to find a steady position in Petersburg. Whereupon he moved to Moscow, in 1880, where he became director of an oil company; in December of the same year he was appointed assistant at the Moscow University.

V.O. Kovalevskiy always strove for a scientific research career, concentrating on paleontology. He is the author of several monographs on the evolution of hoofed animals. In his writings, he convincingly demonstrated that morphologic changes are determined by functional demands which change with the environment. Thus, the emergence of cereals and other angiosperm plants, in the Tertiary, brought about, in Kovalevskiy's opinion, the formation of a reduced leg skeleton, and a development of high-crown teeth. The law of inadaptive and adaptive reduction, as demonstrated by him on the animal hoof, has a general biologic application, in one form or another.

The geologic works of V.O. Kovalevskiy are of considerable interest. They deal chiefly with the correlation of Cretaceous, Jurassic, and Tertiary deposits of different parts of the world. He posed an extremely important question: do the same forms originate simultaneously in different zones? This work of V.O. Kovalevskiy remained unfinished. However, its individual chapters on the Cretaceous-Jurassic boundary, on the Jurassic zoogeographic provinces, and other topics, are of great and independent scientific interest.

He first determined the widespread development of the Cenomanian transgression, and his maps of the Upper Jurassic and Lower Cretaceous were a most valuable contribution to science.

He gave much attention to the study of the Tertiary, because of his interest in the paleontology of large mammals.

V.O. Kovalevskiy died April 28 (16), 1883.

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FIFTIETH MEMORIAL FOR THE FRENCH GEOLOGIST A. LAPPARENT

Albert August de Lapparent was born December 30, 1839, in Bourges (Central France). In 1864 he graduated from the mining school where, among his professors, was L. Ely de Beaumont and other outstanding French geologists.

He began his practice in the Geologic Administration of France. From 1875 on, he took over the chair of geology and mineralogy in Paris Catholic University. He soon abandoned his regional and engineering-geology pursuits and dedicated his efforts to teaching. In that period of his activity he wrote and published a number of text books. His Traite de Geologie (1882) contains a vast amount of material on historical geology and was, in its time, the most valuable manual on the stratigraphy and paleontology of the Earth. Also well known are his texts in mineralogy, geology, mineral fuels, and physical geography (geomorphology). These writings, of a high quality for their time, went through several editions.

His field of scientific interest was broad. He dwelt with problems of stratigraphy, general geotectonics, volcanism, geophysics, glaciology, geomorphology, and also the problems of the general geology of France and the Alpine zone. Of great scientific interest is a geologic map of France in the preparation of which he cooperated.

From 1865 to 1880, A. Lapparent was one of the editors of the Revue de Geologie. He was member of many scientific institutions, and was elected to the Paris Academy of Science, in 1897.

He died May 5, 1908.

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TWENTY-FIFTH MEMORIAL FOR THE SOVIET MINERALOGIST S.F. GLINKA

Sergey Fedorovich Glinka was born September 7 (August 26) 1855, at the Sysertsk Zavod (Urals), and graduated from Petersburg University in 1882. He obtained his Master's degree in 1890, and the PhD degree in 1896.

S.F. Glinka had an extensive teaching career. He taught for a few years in the Institute of Engineers of the Ways and Communications and in the Bestuzhev Institute (for women) and was curator of the Mineralogical Museum at Petersburg University. Subsequently he moved to Moscow to become professor in Moscow University where he taught optical crystallography. In his last years, S.F. Glinka was at the Institute of

pplied Mineralogy (now VIMS).

Outstanding among his early works is his tudy of albite. This was the world's first ttempt at a crystallographic description of lbite. As a result of his study of a large umber of specimens, S.F. Glinka determined the error, great inconsistency in prevailing opinion on the mineralogic forms of his mineral. His conclusions on the peculiarities of crystal combinations and twinning re of interest. That work was awarded the rize of the Petersburg Mineralogical Society.

S.F. Glinka gave serious attention to the on-ore rocks. His text on building materials appeared in 1881. He studied kaolin eposits and proposed a definition according o which any dispersed rock should be called lay, if it forms a plastic mass on wetting.

His observations of the effect of explosive pon gneiss are well known.

S.F. Glinka is the author of a number of exts on crystallography, optical crystallography, and mineralogy, which went through everal editions.

He died April 18, 1933.

TWENTY-FIFTH MEMORIAL TO THE GERMAN MINERALOGIST AND CRYSTALLOGRAPHER V. GOLDSCHMIDT

Victor Goldschmidt was born February 10, 853, in Maintz (Germany). In 1874 he raduated from the Freiberg Mining Academy, nd stayed on as an assistant in a laboratory ourse in testing and as instructor in blow ipe analysis. Later on, he specialized in mineralogy in Munich, under Yu. A. Weissach (1878), in petrography in Heidelberg nder G. Rosenbusch (1879), and in crystalography in Vienna, under M.A. Brejin. His hesis on the application of $2KI.HgI_2$ (Toulet solution) in mineralogy and petrography brought him the degree of doctor of science, Heidelberg, 1880. In 1888 he became assistant professor, and in 1898 professor at that university.

Seeking to find regularity in crystal development, V. Goldschmidt took stock of all the crystalline mineral forms in his three-volume Index der Krystallformen (1886-1891). To perfect crystallographic measurements, he devised a two-circle goniometer and proposed a gnomonic projection for the computation and drawing of crystallographic forms. He published an atlas of all mineral crystallographic forms (9 volumes of text and illustrations). Of importance was his index scale of minerals of different specific gravities. He is the author of the harmonic rule in the development of crystalline forms.

In Heidelberg, V. Goldschmidt set up a special laboratory for perfecting the methods of mineral identification and their crystallographic study. Here, many foreign students received their training, alongside with the Germans.

Specifically, he was visited by A. Ye. Fersman who was carrying on his study of the crystallographic forms of diamonds at that time. As a result, their joint work, Die Diamanten, was published. V. Goldschmidt is the author of some 200 works. In 1914 he founded a periodical, Beitrage zur Krystallographie und Mineralogie.

He died in Salzburg, Austria, May 8, 1933.

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Division of History of Geology,

Geological Institute

U.S.S.R. Academy of Sciences, Moscow

V.V. Tikhomirov and T.A. Sofiano

OBITUARY NOTICES

ALEKSANDR FEDOROVICH SOSEDKO

Aleksandr Fedorovich Sosedko, Senior Scientist of the Yakutian Branch of the U.S.S.R. Academy of Sciences and a Candidate in Geological and Mineralogical Sciences, died on August 27, 1957 following a serious illness.

A.F. Sosedko was born on September 12, 1901 in Sretensk to a military family. After completing high school at the age of 17, he joined the Red Guard in 1918-1919, and participated actively in combatting the counterrevolutionary bands along the Fergana frontier.

He entered the Central Asian University in Tashkent in 1921, and in 1923 transferred to the Moscow Mining Academy. He graduated from that institution in 1929 with the degree of Mining Engineer. In 1924-1925, while a university student, A.F. Sosedko took part in prospecting and research at Tyuya-Muyun. In 1926 and 1927 he headed a geologic party prospecting for mercury and antimony deposits. In 1928 he worked in the Kara-Kum as deputy in charge of the well-known sulfur mine and plant.

Between 1929 and 1935, A.F. Sosedko participated in the Tadzhik-Pamir expedition for the study of rare pegmatite metals in the Turkestan Range and in the Kyzyl-Kum. Along with A. Ye. Fersman, he had a part in the discovery and study of copper-nickel deposits in the Monche-Tundra and of the Khibiny apatite-nephelite deposits on the Kola Peninsula.

In subsequent years he did research in the Ural Mountains, Central Asia, and on the Kola Peninsula. During World War II he was at work in the Ural Mountains.

In 1950, Sosedko began work in the Kola Branch of the U.S.S.R. Academy of Sciences, and did research on rare pegmatite metals until his death. His long years of experience in the field of mineralogy and geochemistry, his keen sense of observation and his broad erudition aided him in making several important discoveries. These resulted in his receiving an award from the Presidium of the U.S.S.R. Academy of Sciences in 1952.

He was the author of more than 50 works on pegmatites in Central Asia, the Urals, and the Kola Peninsula. The most important of these include: "Pegmatites in Altyn-Tau, Central Kyzyl-Kum" (1932); "Materials on the Mineralogy and Geochemistry of Altyn-Tau Pegmatites" (1935); "Pegmatites in the Southern Slopes of the Turkestan Range" (1937); "Albite Pegmatites in the Central Arc of Central Asia" (1936); "Basic Characteristics of Pegmatite Fields in the Turkestan Range" (1940); and "Cesium and Lithium in the Il'men Range of the Ural Mountains" (1938). These and other of his works contain his theories on zoning in pegmatite fields and the conclusions which were used extensively by A. Ye. Fersman in his monograph entitled "Pegmatites" (1940), and which constitute the guiding principles for research on various types of pegmatites.

Shortly before his death, A.F. Sosedko completed a major monograph on the mineralogy and geochemistry of rare pegmatite metals on the Kola Peninsula which he intended to present as the thesis for his doctorate in geologic and mineralogic sciences.

Many of his works describe deposits of rare elements and minerals and their geochemistry. He did valuable research on the study of Central Asian deposits of emery. Sosedko introduced the theory of agglomeration of iron and manganese in Central Asia during the Upper Silurian, along with aluminum, and the possibility of finding sedimentary deposits of these metals in the Paleozoic of Central Asia. As is widely known, Sosedko's theories were confirmed by the discovery of several manganese and iron ore deposits of this type.

Sosedko and his theories contributed to the discovery of more than 300 different ore deposits in Central Asia, the Urals and on the Kola Peninsula. Many of these are currently being mined.

Sosedko wrote more than 120 scientific works, most of which have been published. He was a member of the All-Union Mineralogic and Geographic Society.

All those who knew Aleksandr Fedorovich Sosedko remember him warmly as a talented

entist and a splendid, modest man.

V.V. Lapin and A.I. Tsvetkov

PETR ANDREYEVICH VOLKOV

Petr Andreyevich Volkov died on October 1957. He was born on October 21, 1889 Cherepovets city, Novgorod Guberniya. In 1 he graduated from the Chemistry partment of the Leningrad Polytechnic titute.

From 1918 on, he worked at the Academy Sciences, first as a member of the Commission on Natural Resources in Russia PS) and later on the radium staff of the nmission, which became the State Radium titute in 1922. In 1929 Petr Andreyevich ied the Institute of Geological Sciences re he worked as a Senior Scientist until end of his life.

In 1936 he earned the degree of Candidate Chemical Sciences without defending a sertation. For the completion of government work, he was granted the Order of the mbol of Honor." He was also awarded the der of Lenin" for his long years of vice.

P.A. Volkov was a remarkable analytical mist and a talented engineer-technologist. was one of the pioneers in radium rerch in Russia. He converted problems of analytical and laboratory nature into hnologic processes.

His first scientific work dealing with equirium research in barium and lead chloride utions was done under the guidance of G. Khlopin and N.S. Kurnakov. His major k was on ways of obtaining high content ium compounds. This constituted the ndation for the first radium stock in ssia in 1923-1924, in the radium plant the struction of which he had supervised in 1. He also organized the chemical labtory at the mine; during the course of years (1924-1926), he did important lytical work on ores and schists, and covered and described the new mineral geite.

In 1926 Petr Andreyevich studied the sul- deposits in Shor-Su and Kara-Kum. He eloped a new method of melting sulfur, proved that when heated in an autoclave, a-Kum ore mixed with water breaks n into two components. The melted sul-, despite its lower specific gravity, colts at the bottom, while in this process, sand separates to form a layer above sulfur. The sulfur thus obtained is of great purity. It contains only 0.1 percent ash and insignificant traces of moisture and organic matter. As a result of sulfur extraction by this method, the first experimental plant in the U.S.S.R. making use of the process was constructed (1927-1929). Later, in 1933-1934, P.A. Volkov designed and organized production of two large sulfur production plants.

Between 1933 and 1941, Petr Andreyevich did technologic research on the Khibiny ores. He developed methods for separating nephelite with sulfuric and sulfurous acids for the purpose of obtaining silica gel and alum; for obtaining rare earths from lovchorrite and apatite; for extracting CaO from apatite; etc.

During the war Petr Andreyevich was in charge of the analytical laboratory of the Ural Branch of the U.S.S.R. Academy of Sciences in Sverdlovsk. After 1944 he was in charge of the Central Chemical Laboratory at the Institute of Geological Sciences of the U.S.S.R. Academy of Sciences.

In 1946 Petr Andreyevich headed a special group working on the development of methods of determining small admixtures in pure metals. He personally developed a simple but brilliant method of determining uranium. It is characterized by extreme accuracy and speed, and is widely practiced now as "Volkov's method."

There was nothing pedantic in his work and always a creative element.

Petr Andreyevich was a gregarious person with broad and varied knowledge. He was an interesting conversationalist who enjoyed universal respect and the sincere affection of his colleagues, students and all co-workers.

I. Borneman

YAKOV IOSIFOVICH OL'SHANSKIY

Yakov Iosifovich Ol'shanskiy, Doctor of Chemical Sciences, Head of the Hydrothermic and Hypergenic Experimental Laboratory at the Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry (IGEM) of the U.S.S.R. Academy of Sciences, died suddenly during the night of January 6, 1958, at the age of 46. A great researcher and experimenter in the field of petrogenesis and ore formation was lost to Soviet science.

Ya. I. Ol'shanskiy graduated from the Novocherkassk Polytechnic Institute in electrochemistry in 1934. In 1939, he completed post-graduate studies in the Department of Physical Chemistry, defending his Candidate's

thesis. He then continued experimental research and taught courses in physical and chemical thermodynamics at that Institute.

Between 1939 and 1946 he served in the Soviet Army. From 1946 until his death he worked at the IGEM of the U.S.S.R. Academy of Sciences.

There, he began his experimental work in research on the balance in the Fe-FeO-FeS-SiO_2 system. It was on the basis of this research material that he prepared and defended the dissertation for his doctorate in chemical sciences, which he obtained in 1952. The scientific conclusions derived from this research are important because they involve the theory of the formation of magma-sulfide deposits, and considerable material on the theory and practice of metallurgical processes.

A second important line followed by Ya. I. Ol'shanskiy in his research was the determination of the solutility of sulfides in water solutions under hydrothermal conditions. In extremely accurate experimentation which completely excluded the margin of doubt usual in such work, he succeeded in making substantial corrections in the data provided by foreign scientists, and in proving the true possibility of the formation of hydrothermal sulfide ores by a process of dissolution, migration and deposition of ores.

The original research done by Yakov Iosifovich in the field of combined migration of substances in the solid and liquid (and gaseous) states is of great interest. He provec the possibility of such phenomena under natural conditions, which had never previo been mentioned in geologic literature.

In recent years, his scientific interest been concentrated on research on the balan of nonmixing liquids in silicate and other fusions containing fluorine and other anions with the purpose of developing a physical-chemical theory on magmatic liquation.

Yakov Iosifovich used extremely novel a original methods in physical-chemical expe mentation. He developed a method of high temperature filtration for the determination heterogeneous balances, a method of "fallin grains" for determining the temperature of melting refractory matter, a method for th capillary separation of a liquid stage for th determination of eutectic structures, a method for determining the solubility in wa of matter which is difficult to dissolve at high temperatures, and many others.

During his work at the Institute, Ya. I. Ol'shanskiy published more than 40 scientifi works.

A brilliant experimental worker with a broad scientific outlook and tremendous er tion, Yakov Iosifovich Ol'shanskiy was an active member of the Institute's staff, a fi scientific mentor of youth, and a sensitive and responsive friend.

V.V. Lapin and A.I. Tsvetkov

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